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(Continuing the Journal of the Allied Dental Societies)

A journal of stomatology; devoted to the advancement and dissemination of knowledge pertaining to the mouth and teeth, and to their relations to the body as a whole

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ANNOUNCEMENT PERTAINING TO DELAY IN THE ISSUANCE OF THE FIRST NUMBER OF THIS JOURNAL

Unavoidable circumstances, some of them inherent in the situation attending the establishment of this JOURNAL, prevented prompt issuance of the initial (March) number. All obstacles in the way of regular publication, hereafter, have been removed. Every assurance can be given that each successive issue will be published promptly at the end of the corresponding *quarter* of the calendar year—until the numbers appear more frequently.

During the period of enforced delay referred to above, material sufficient to fill both the March and June numbers was prepared for publication. Half of it was issued as the delayed March number; the other half is issued herewith as the June number.

The September number will be closed on August 8. Secretaries of Societies who may wish to present manuscripts for publication in the September number are urgently requested to *forward their manuscripts to the editorial office before August 8.*

THE ENDOWMENT FUND IN SUPPORT OF THIS JOURNAL

All who receive copies of this JOURNAL are requested to read the report on page 33 of the March number, and on page 203 of this number, regarding the initial contributions to this fund. All who may be interested are invited to coöperate in increasing the fund for the support of this JOURNAL and the furtherance of its objects. It is particularly important that prospective contributors should understand that donations to this fund, in any amount whatever that donors may be able to give, will be gratefully accepted.

All the money already paid into this fund has been invested in Victory-Liberty Bonds.

Annual reports on the use of the proceeds of this fund will be published in this JOURNAL.

APPEAL FOR COÖPERATION IN PREVENTING A SHORTAGE IN THE AVAILABLE SUPPLY OF COPIES OF THE JOURNAL OF DENTAL RESEARCH

It is an almost universal experience, in the history of successful journals, that a shortage in the supply of early numbers and volumes soon eventuates. All who receive copies of this number are requested to coöperate with the JOURNAL OF DENTAL RESEARCH in preventing such a shortage, *by preserving their copies or affording the* JOURNAL *an opportunity promptly to repurchase copies that may not be needed.* Copies of the JOURNAL that may not be desired permanently by subscribers would be accepted by the JOURNAL as contributions to its endowment fund, with the understanding that the proceeds of the sale of such second-hand copies would be duly credited to the donors of the corresponding numbers or volumes.

CRITICISM INVITED

Readers of this JOURNAL are cordially invited to suggest improvements of it, to the end that all concerned may collaborate in making the JOURNAL OF DENTAL RESEARCH successful and representative in the highest degrees attainable.

A CONTRIBUTION TO THE KNOWLEDGE OF THE DEVELOPMENT OF THE SUBMAXILLARY AND SUBLINGUAL SALIVARY GLANDS IN HUMAN EMBRYOS

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Although the stomatologist is well aware of the importance of the salivary glands, both in regard to their physiological function and to the influence of their secretion on the condition of the teeth, he has given little or no attention to the development of these organs. Of the anatomists, very few have made a detached study of this subject and the number of human embryos which have been studied for this purpose is too limited to comprise the basis for a comprehensive knowledge.

Chievitz of Copenhagen published, in 1885, an admirable work, "Beiträge zur Entwickelungsgeschichte der Speicheldrüsen," upon which most of our present knowledge is based. He describes detailed observations on embryos of six, eight, ten and twelve weeks, and some findings in two older specimens. Bujard of Geneva published, in 1911, an article, "Reconstructions plastiques des glandes salivaires d'un fœtus humain de 10 semaines environ." His excellent observations are all based upon a 35 mm. embryo (tête siège). The fourth volume of "Studies in Cancer and Allied Subjects," issued by Columbia University, contains the result of a careful study, by Schulte, of the human salivary glands of three embryos. The embryos are nos. 229, 325 and 3 of the Columbia collection and measure 7.5 mm., 20 mm. and 22 mm., respectively. Besides these there are a few short remarks of importance found in articles by His, 1885 (embryos 12.5, 13.8 and 18.5 mm. in length), Hammar, 1901, Stöhr, 1905, and Paulet, 1911 (embryo, 14.7 mm. in length).

CONSIDERATION OF THE GROSS ANATOMY

Most anatomists have given but a very inaccurate description of the submaxillary and sublingual salivary glands. The former is usually said to be a body of irregular form with a duct leading to the caruncula sublingualis; the latter, a much smaller gland separated from the submaxillary by the mylohyoid muscle, with from 8 to 20 excretory ducts of which one may be of larger size opening near the submaxillary duct in the sublingual papilla. Carmalt has given us, in the fourth volume of "Studies in Cancer and Allied Subjects," the result of his careful dissection of injected specimens, which show that the submaxillary gland is quite frequently of complicated structure, while the so-called sublingual gland is in fact made up of one large sublingual gland, which is not constant, and a number of smaller ones. This fact had already been observed by Chievitz, who calls the latter glandulae alveololinguales. Carmalt gives a great many beautiful reproductions of prepared human specimens illustrating the following facts.

The *submaxillary gland* varies in form not only in different individuals but also in the two sides of the same person. It consists of a main gland which is placed dorsocaudal to the free border of the mylohyoid muscle, around which the duct turns to reach the floor of the mouth. It is usually divided into three or four large lobes by incisures which penetrate to the hilus. Frequently there are one or more smaller glands varying greatly in position and arrangement. They are, for the most part, placed above the mylohyoid muscle, draining from the dorsal as well as the ventral side into the main submaxillary duct. These are called accessory glands. Occasionally a ventral gland is developed more independently and placed more anteriorly, so that it comes in close relation to the sublingual glands. Its duct, which opens into the main duct further forward, also has a characteristic appearance, being longer than the ducts of the ordinary accessory glands. To such a gland, Carmalt gives the name of secondary gland. A ventral accessory submaxillary gland was also found by Bujard in his 35 mm. embryo.

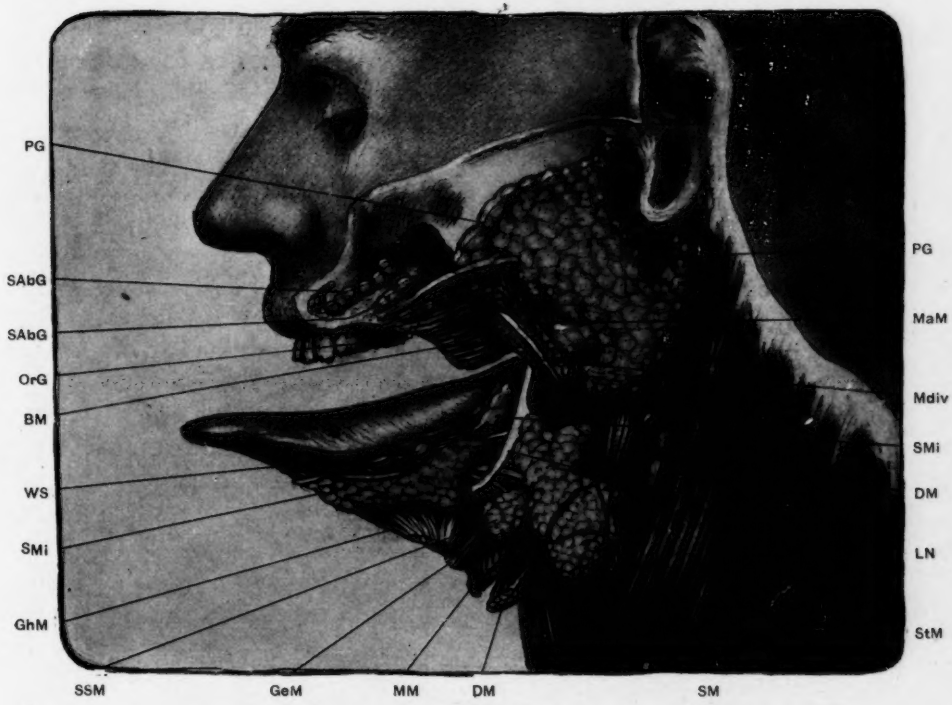

FIG. 1. DEEP DISSECTION OF ADULT HUMAN SALIVARY GLANDS OF THE LEFT SIDE, COLUMBIA UNIVERSITY MORPHOLOGICAL MUSEUM, NO. 2305 (CARMALT)

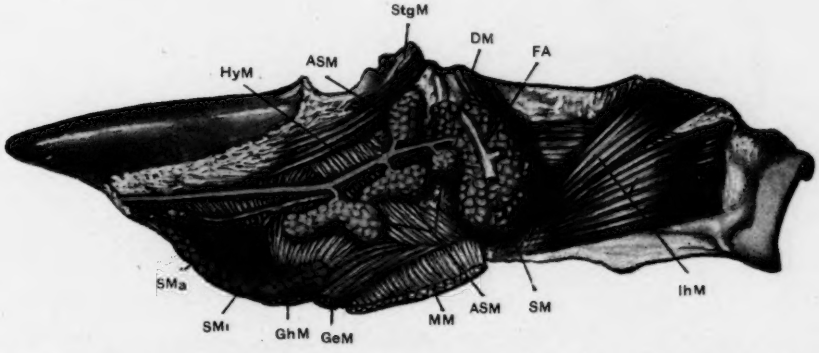

FIG. 2. DEEP DISSECTION OF ADULT HUMAN SALIVARY GLANDS OF THE LEFT SIDE, COLUMBIA UNIVERSITY MORPHOLOGICAL MUSEUM, NO. 1980 (CARMALT)

The *larger sublingual* (*Bartholinian*) *gland* (sublingualis major) is not constantly found in man. It sometimes develops on one side and is absent on the other. If present it is usually situated medially to the lesser sublingual glands. Its duct extends forward and upward toward the floor of the mouth directed toward the median line, where it either joins the terminal part of the submaxillary duct or opens independently on the parafrenular papilla.

The *lesser sublingual* (*Rivinian*) *glands* (sublinguales minores) are a group of smaller glands, each provided with a small duct opening on the plica sublingualis (ducts of Rivini). If the larger sublingual gland is present, these lesser glands become reduced in size and extent, while on the other hand they develop to much greater size if the sublingualis major is absent.

For better orientation let us briefly review the location and nomenclature of the various sulci of the floor of the mouth (*figs. 3* and *4*).

An explanation of "leaders for all illustrations" is summarized on page 143..

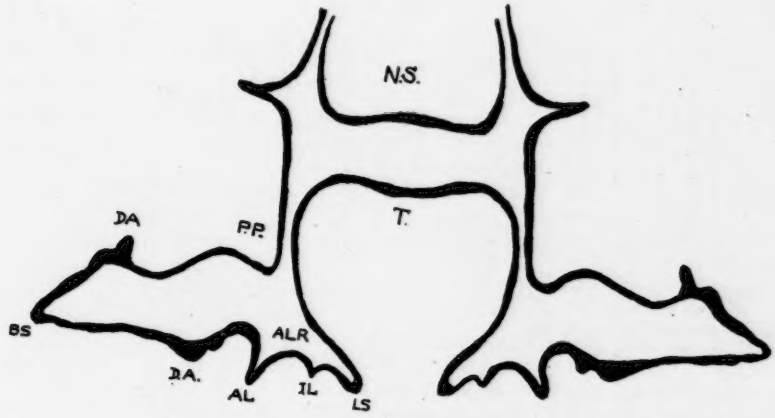

FIG. 3. CAMERA LUCIDA OUTLINE OF THE ORAL EPITHELIUM OF A 20 MM. EMBRYO IN FRONTAL SECTION (SCHULTE)

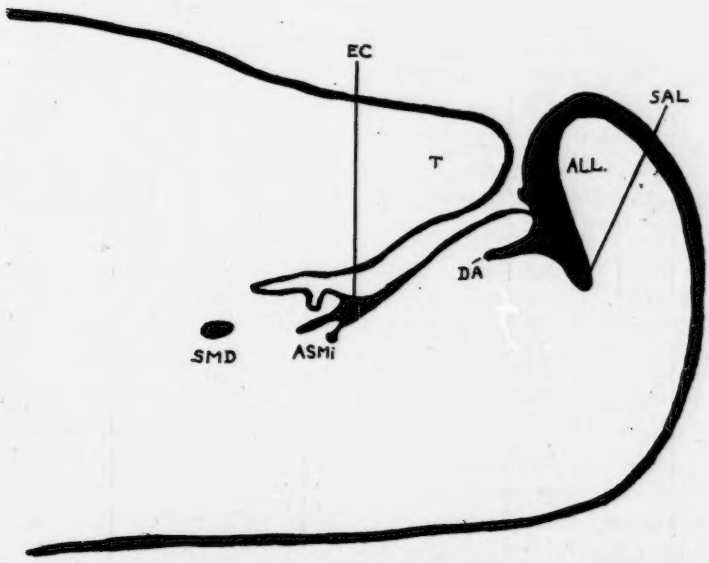

FIG. 4. CAMERA LUCIDA OUTLINE OF THE ORAL EPITHELIUM OF A 31 MM. EMBRYO IN SAGITTAL SECTION

TABLE 1

Data on embryos examined by the author

SIZE	PROBABLE AGE (KEIBEL & MALL)	EMBRYO—SERIES NUMBER	SECTIONS ILLUSTRATED—NUMBER	DIRECTION OF SECTIONS THROUGH HEAD	STAINING METHOD	REMARKS
mm.	*days*					
10.0	40	1000	251	Transverse frontal	Borax, carmine and Lyons blue	
10.2	40	736	125	Sagittal	Borax, carmine and Lyons blue	
11.0	42	2036	None	Transverse frontal		
11.5	43	189	None	Transverse frontal		
11.7	43	1605	None	Transverse frontal		
12.0	44	816	259	Transverse frontal	Borax, carmine and Lyons blue	
13.6	45	839	265	Transverse frontal	Borax, carmine and Lyons blue	
18.1	50	1129	227	Sagittal	Borax, carmine and eosin	Harvard Embryological Collection
20.0	52	2037	339	Sagittal	Cochineal and Orange G.	
			268			
22.0	54	851	248	Sagittal	Borax, carmine and Lyons blue	
			279			
			289			
			295			
28.8	59	1598	276	Sagittal	Borax, carmine and Orange G.	
			233			
31.0	61	1706	332	Sagittal	Cochineal and Orange G.	
			341			
			343			
			362			
32.0	63	290	None	Sagittal		
47.0	73	4	46	Sagittal	Hematoxylin and eosin	
			62			
			73			
			80			
			83			
			93			Specially prepared sections through head
			98			
			102			
			154			
			163			
			249			
			278			

TABLE 1—*Continued*

SIZE	PROBABLE AGE. (KEIBEL & MALL)	EMBRYO—SERIES NUMBER	SECTIONS ILLUSTRATED—NUMBER	DIRECTION OF SECTIONS THROUGH HEAD	STAINING METHOD	REMARKS
mm.	*days*					
52.0	76	2	172 20	Transverse frontal	Hematoxylin and eosin	
62.0	90?	5	32 39 46 82 157	Sagittal	Hematoxylin and eosin	Specially prepared sections through head
230.0	182	6	52 58 79	Sagittal	Hematoxylin and eosin	Only anterior part of mouth

THE WRITER'S OBSERVATIONS

The various authors who have studied the development of the salivary glands, in human embryos, used for the purpose frontal sections through the head. In the opinion of the writer serial sections in the sagittal plane should prove of greater advantage. They give a clearer idea of the direction of the developing glands, their ramification and relation to adjoining structures of the mouth. I was fortunate enough to have at my disposal a large number of specimens (serial sections), from the Harvard Embryological Collection cut in the sagittal plane, but I had to prepare specially the heads of a few embryos in more advanced stages. The further purpose of my study was to furnish more complete data concerning the time of development of the anlagen of the submaxillary, sublingual minor and major, the anterior lingual and the labial glands. I gave special attention to the place from which the development of the anterior lingual gland starts, as Schulte found in *embryo 325* of the Columbia collection a sprout mesad from the submaxillary anlage, which he thinks may form the anterior or apical gland of the tongue (Nuhn-Blandin). The time, location and frequency of the development of accessory and secondary lobes of the submaxillary gland promised another interesting study, to which sagittal sections are specially well adapted.

A great deal more time than was at my disposal could be spent in observing the changes in the epithelial growth and the reaction produced in the surrounding mesenchyma.

DESCRIPTION OF THE DEVELOPMENT OF THE SALIVARY GLANDS IN THE EMBRYOS EXAMINED

Embryo 1000 of the Harvard collection—length, 10 mm.

Parotid gland. In *section 251* the epithelium shows a thickening, almost forming a semi-circle around the buccal sulcus. This is the anlage of the parotid gland. No other gland is seen in this specimen. (See *fig. 5*).

Embryo 736 of the Harvard collection—length, 10.2 mm.

Submaxillary gland. Section 125 shows a sagittal view of an embryo in which the lips have not yet become separated from the structures within the mouth. The tongue is distinctly visible. Anterior to the tongue we find an epithelial thickening, a band of considerable length. It is my opinion that from this the anlage of the submaxillary gland is developed. No other organs of the mouth have yet developed.

Embryos 2036, 189 and 1605 of the Harvard collection—length, 11 11.5 and 11.7 mm., respectively

Submaxillary gland. The transverse frontal sections of these three embryos all show the anlagen of the parotid gland, but none of the submaxillary or sublingual glands.

Embryo 816 of the Harvard collection—length, 12 mm.

Submaxillary gland. In frontal *section 259* we see the anlagen of the submaxillary glands. They start from the lingual sulcus of the oral epithelium just above the place where the lingual nerve, infiltrated by the ganglion, crosses and enters the substance of the tongue.

Embryo 839 of the Harvard collection—length, 13.6 mm.

Submaxillary gland. Transverse *section 265* shows the submaxillary anlage posterior to the lingual nerve, which crosses the lingual

sulcus in *section 272*. The epithelial sprout is further developed than in *embryo 816*. It is dumb-bell shaped and a distinct change in the mesenchyma is visible. The connective tissue cells have become condensed, forming a capsule which surrounds the epithelial sprout. This is shown in the high-power photomicrograph of this section. (See *fig. 9*).

Embryo 1129 of the Harvard collection—length, 18.1 mm.

Submaxillary gland. No. 227 of the serial sagittal sections shows that even at this stage the alveolar part has not yet become separated from the lip, although in *section 120* we find the labial lamina well formed. *Section 127* shows the anlage of the submaxillary gland extending backward from the anterior margin of the tongue. The oral epithelium shows a marked thickening anterior to this part, which is identical with the band seen in *embryo 1000*. Ventral to the epithelial sprout is the submaxillary ganglion.

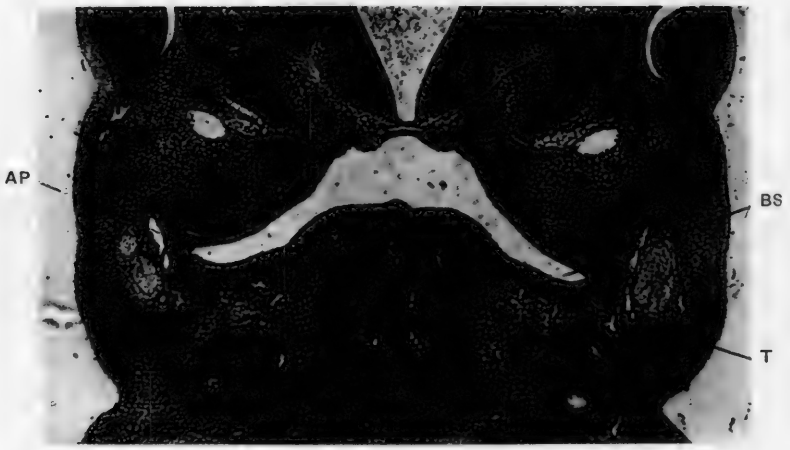

FIG. 5. EMBRYO 1000, H. E. C., LENGTH 10 MM., SECTION 251

FIG. 6. EMBRYO 736, H. E. C., LENGTH 10.2 MM., SECTION 125

FIG. 7. EMBRYO 816, H. E. C., LENGTH 12 MM., SECTION 259

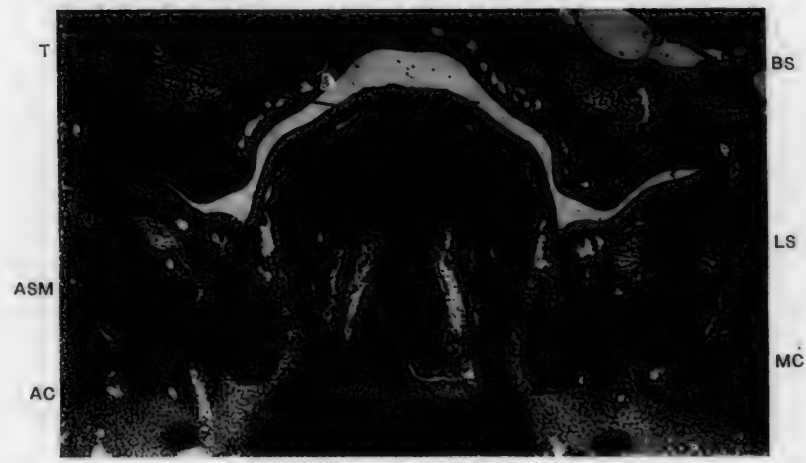

FIG. 8. EMBRYO 839, H. E. C., LENGTH 13.6 MM., SECTION 265

FIG. 9. EMBRYO 839, H. E. C., LENGTH 13.6 MM., SECTION 269 (HIGH POWER)

FIG. 10. EMBRYO 1129, H. E. C.. LENGTH 18.1 MM., SECTION 227

Embryo 2037 of the Harvard collection—length, 20 mm.

Submaxillary gland. This specimen is a little older than *embryo 1129*. The advance in the development of the submaxillary gland is, however, very marked, which indicates the rapidity of growth of this organ in its early development. The dental lamina is well-formed at this stage. The submaxillary gland shows five branches in sagittal *section 239*, which is quite a distance from the median line. In *section 266* we see the place where the epithelial cord is given off from the comb, formed from the oral epithelium. The future duct is still solid along its entire course.

The greater sublingual gland. From the middle of the ventral aspect of the comb, referred to above, a bud is about to form, which is probably the first indication of an anlage for the sublingualis major gland. (See *sec. 266, fig. 11.*)

FIG. 11. EMBRYO 2037, H. E. C., LENGTH 20 MM., SECTION 266

FIG. 12. EMBRYO 2037, H. E. C., LENGTH 20 MM., SECTION 239

Embryo 851 of the Harvard collection—length, 22 mm.

Submaxillary gland. In *section 248* we see the opening of the duct into the floor of the mouth. Previous slides show that its lumen has been partly formed as far back as the mylohyoid muscle. If we follow the duct backward we find that soon a branch is given off, which is the anlage for the sublingualis major gland. On the other side the submaxillary duct runs more nearly parallel with the plane of the section. Its opening is seen in *section 276*. If we follow the sections laterally we find that on this side, also, a branch is formed ventrad (*sec. 278*) anterior to the place where the duct, proceeding backward, passes over the submaxillary ganglion. A sprout is given off here (*sec. 289*). The main duct then curves down behind the mylohyoid muscle. The formation of its lumen has also on this side proceeded as far as this point. Here several branches are formed (*sec. 294*). The branches are solid epithelial cords from which buds sprout in various directions (see *fig. 18*). All are enclosed by condensed connective tissue cells, forming at this stage a capsule which is easily recognized (*sec. 295*). The sprout, seen in *section 289*, is entirely apart from the main gland and not included in its capsule. It represents the anlage of a ventral accessory submaxillary gland (see *fig. 17*). No such condition was found on the other side.

The greater sublingual gland. The anlage of this gland is present on both sides. Its origin has already been described in connection with the submaxillary ducts. On the first side a branch of slightly smaller size is given off, ventrad and laterally, a short distance from the orifice of the duct (*sec. 242*). In *section 240* the cross sections of the two ducts are easily recognized. On the other side we find the branch in *section 278*, from which place oblique sections can be followed backward in the succeeding sections. *Section 279* already shows the two ducts quite a distance apart. The sublingualis major duct, still one solid cord, presents two branches of equal size in *section 288*, comprising a glandular mass, the outline of which indicates the formation of buds, as seen in *section 289*. The mesenchyma surrounding the anlage of the sublingualis major shows little reaction at this stage, two or three layers of connective tissue cells surrounding it loosely in concentric arrangement being the only indication of a capsule.

The lesser sublingual glands. Several anlagen of lesser sublingual glands are visible in this embryo. On each side two small sprouts are seen developing from the epithelial band anteriorly to the opening of the submaxillary duct. One of these is seen in *section 248*. If we proceed in a lateral direction we find two or three more of still smaller size, all in the anterior portion of the mouth.

FIG. 13. EMBRYO 851, H. E. C., LENGTH 22 MM., SECTION 248

FIG. 14. EMBRYO 279, H. E. C., LENGTH 22 MM., SECTION 279

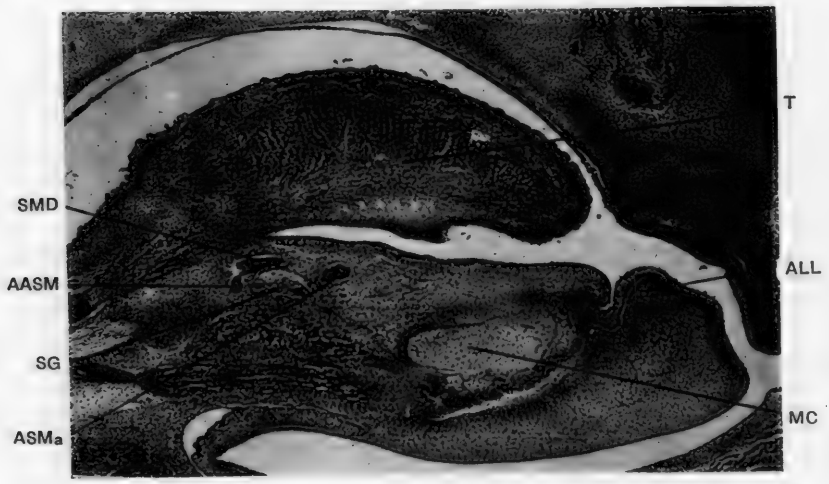

FIG. 15. EMBRYO 851, H. E. C., LENGTH 22 MM., SECTION 289

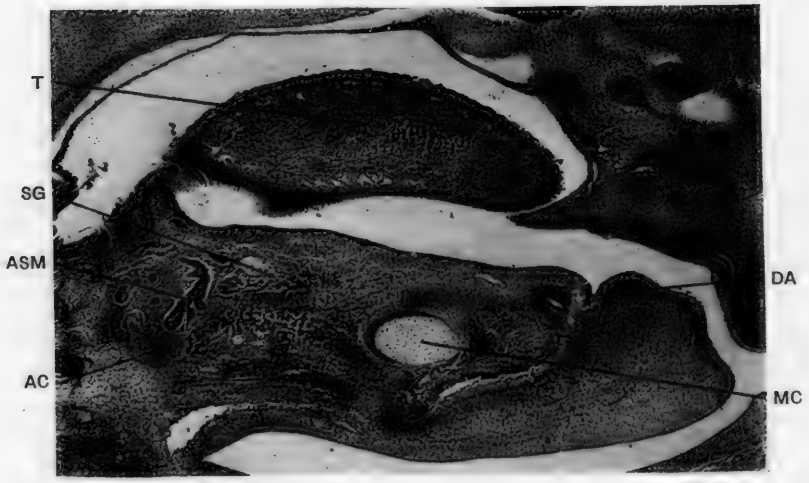

FIG. 16. EMBRYO 851, H. E. C., LENGTH 22 MM.. SECTION 295

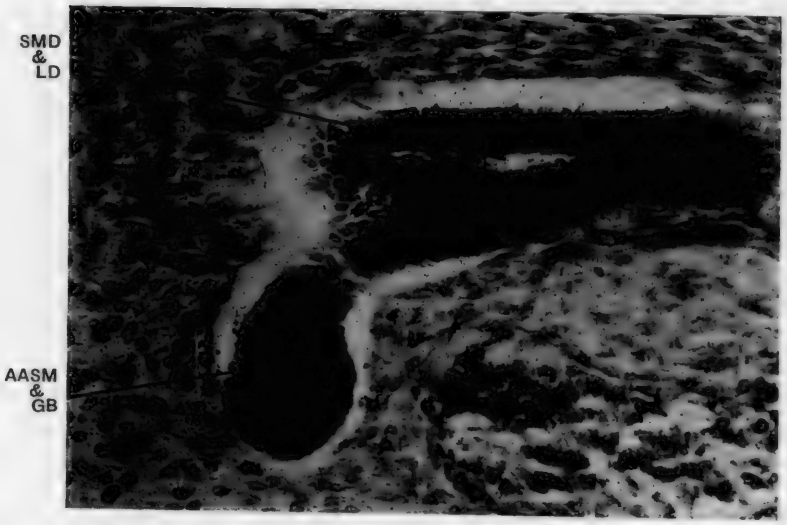

FIG. 17. EMBRYO 851, H. E. C., LENGTH 22 MM., SECTION 289 (HIGH POWER)

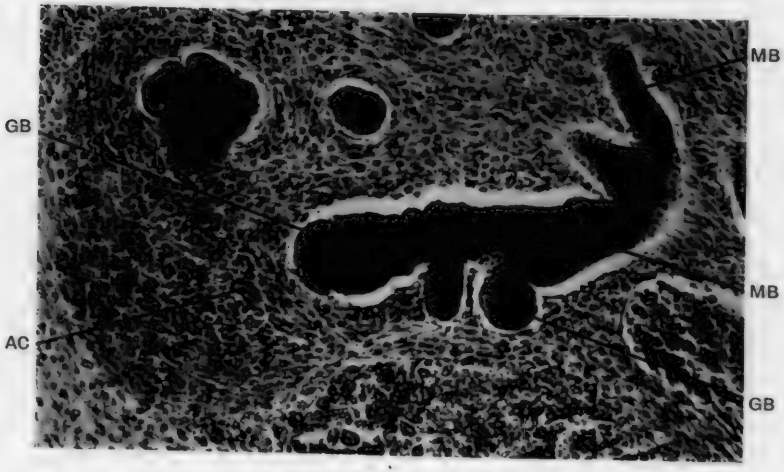

FIG. 18. EMBRYO 851, H. E. C., LENGTH 22 MM., SECTION 295 (HIGH POWER)

Embryo 1598 of the Harvard collection—length, 28.8 mm.

In this embryo the conditions on the two sides are almost identical, so that a description of one side will be sufficient.

Submaxillary gland. The orifice of the submaxillary duct is seen in *section 259* on one side and in *section 274* on the other. It has a wide lumen which can be followed as far back as the place where the duct curves down ventrad after it has passed over the submaxillary ganglion. Branches are then given off that ramify in the connective tissue, which has formed a distinct capsule. Proliferation of the epithelium is quite marked at this stage, as is indicated by the large accumulation of cells in the many buds found on the various branches (see *sec. 233*).

Greater sublingual glands. *Sections 258* and *275*, both next to the sections which show the orifice of the submaxillary ducts, in a lateral direction show a small sprout growing ventrad from the anterior margin of the opening of the duct (see *sec. 275*). These are probably anlagen of the greater sublingual glands. They are visible in only two sections on each side and show no sprouts or branches yet. While their size and location might give us the right to call them anlagen of greater sublingual glands, it is also possible that they are lesser sublingual glands and that their larger size is in accordance with their anterior position.

Lesser sublingual glands. Three very short round sprouts are given off from the oral epithelium, one of which is shown in *section 253* and the other two in *sections 249* and *250*. These are located further away from the median line and are also further caudad than the orifice of the submaxillary duct. Three or four similar sprouts are seen on the other side, all of which are considerably shorter than the sprout of the sublingualis major, being rounder and only about one quarter of its length with the exception of the anterior one on the other side, which is almost two-thirds the size of the sublingual major, but not so thick.

FIG. 19. EMBRYO 1598, H. E. C., LENGTH 28.8 MM., SECTION 275

FIG. 20. EMBRYO 1598, H. E. C., LENGTH 28.8 MM., SECTION 233

Embryo 1706 of the Harvard collection—length, 31 mm.

Submaxillary gland. The opening of the duct is seen in *section 323* on one side and *291* (see illustration) on the other. It describes a curve, not only in a ventral direction but also toward the median line. The most medially located part of the duct is, therefore, seen in *section 297*, where a sprout is given off. In *section 296* a longer sprout is visible. In the succeeding sections two cross sections through the submaxillary duct are found, until the caudal one joins the oral epithelium and forms its orifice (see *sec. 291*). If we follow this duct on the other side about one-third of its course we find, in *section 326*, a branch given off which accompanies the main duct at its ventral side (see *sec. 332*). This is a condition corresponding to the one found in *embryo 851, section 279*, except for the fact that in the latter the main duct appears ahead of its branch in a posterior direction, indicating a course toward the median line, the direction in which the ductus sublingualis major grows. In *embryo 1706*, however, the reverse is seen (*sec. 332*), indicating a slightly more lateral direction taken by the secondary than by the main duct. This distinction, and the extremely posterior position of the anlage of the gland body, pronounce this a secondary lobe of the submaxillary gland. In *section 341* the secondary duct takes a turn ventrad. A lumen has already formed in its duct which can be followed to this point. In *section 343* three round buds are seen, which form the branches of this small submaxillary component. A condensation of the surrounding mesenchyma indicates the formation of a capsule. If we proceed further laterally we come to the main body of the submaxillary gland, which is seen in *section 362*. It is located below the submaxillary ganglion and at the posterior border of the mylohyoid muscle. On the other side the development of the anlage of the secondary lobe has started further back and has not progressed so far. The branch is given off in *section 284* about half way between the orifice of the main duct and the body of the gland.

The greater sublingual gland. The submaxillaris major is missing on one side, but on the other side a sprout is given off from the main duct at the place where it turns to follow a posterior course.

This sprout has already acquired a lumen, as seen in *section 297* and a small glandular head appears in the two sections on either side.

The lesser sublingual glands. Lesser sublingual glands are given off both from the epithelial comb anterior to the submaxillary duct near the median line and posteriorly where smaller buds are seen in lateral sections (see *sec. 291* and *343*).

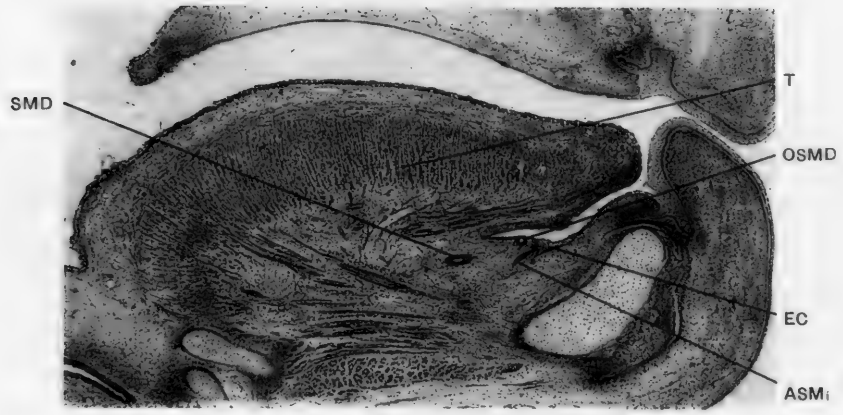

FIG. 21. EMBRYO 1706, H. E. C., LENGTH 31 MM., SECTION 291

FIG. 22. EMBRYO 1706, H. E C., LENGTH 31 MM., SECTION 297

FIG. 23. EMBRYO 1706, H. E. C., LENGTH 31 MM., SECTION 332

FIG. 24. EMBRYO 1706, H. E. C., LENGTH 31 MM., SECTION 341

FIG. 25. EMBRYO 1706, H. E. C., LENGTH 31 MM., SECTION 343

FIG. 26. EMBRYO 1706, H. E. C., LENGTH 31 MM., SECTION 362

Embryo 290 of the Harvard collection—length 32 mm.

Submaxillary gland. In *section 196* the submaxillary duct passes down vertically to the floor of the mouth. It soon bends caudad, however, almost at right angles and passes backward until its course is again changed, when it passes ventrad behind the mylohyoid muscle. No seconday or accessory glands have been found.

Greater sublingual glands. No greater sublingual gland has been found.

Lesser sublingual glands. Five or six sprouts are seen in the various sections, given off from the posterior part of the epithelial band, already described, in younger embryos. Near the median line they are largest and closest to the anterior part of the mouth, while the more lateral the section the smaller is the sprout and the further caudad its position. Only one half of the embryo has been cut in sagittal sections. As it presents nothing specially new and records no further progress than *embryo 1706*, no illustration of this series is added.

Embryo 4, Special—length 47 mm.

This embryo is approximately ten and one half weeks old. Serial sections were made of the face in sagittal plane. Unfortunately it was not quite sufficiently decalcified, which resulted in the tearing of some of the sections.

Submaxillary gland. The orifice of the submaxillary duct is seen in *section 96*. Its first part describes not only the regular curve but also an inclination toward the median line, so that two sections through the duct may be seen in all sections from 96 to 108 (see *sec. 102*, which is cut through the most medial part of the curve). *Section 98* is very near the outlet of the duct. The sublingual gland which is seen in this section is not connected with the duct. If we follow the duct backward we find it cut obliquely and a higher magnification (of *sec. 80*) is shown in *figure 30*. Still further back in *section 73* we come to a place where two branches are given off. On the ventral side an accessory duct curves cephalad. It has already acquired a lumen and belongs to the accessory submaxillary gland placed over the mylohyoid muscle (see in *sec. 98*). A dorsal accessory duct branches from

the same part of the main submaxillary duct; the latter continues in a ventral direction and forms the main part of the submaxillary gland. The main part of the submaxillary gland is seen in *section 46*. Its main branches show at this stage a lumen extending into the side branches, from which new buds are given off. *Figure 33* shows a higher magnification of a duct with side branches and buds which are to form the end pieces of alveoli. The epithelium at this stage is still in a state of proliferation. The other side of the embryo shows similar development of the main gland, but no accessory glands.

Greater sublingual gland. It is the writer's opinion that there are no greater sublingual glands in this specimen, although one might be tempted to take one of the well-developed lesser sublingual glands for a sublingualis major (see *sec. 98*). Its ducts, however, are of smaller size than the ductus sublingualis major has appeared to be in previous specimens and show scarcely any indication of a lumen.

Lesser sublingual glands. On one side of the embryo a large sublingual gland is given off laterally from and slightly anterior to the submaxillary orifice. Its duct is of moderate size, and not connected with the submaxillary duct. Part of it is seen in *section 154* and its head, from which several buds are formed, is seen in *section 163*. Seven or eight sprouts in all are given off from the sublingual region at various places. They are small in the lateral section, while towards the median line they become larger and are placed further toward the anterior part of the floor of the mouth (see *sec. 249*). On the other side of the embryo two large sublingual glands are found in the anterior part, starting slightly lateral and anterior to the submaxillary orifice. They both grow in a ventral direction at an angle of about 45 degrees, their course being also inclined toward the median line. In *section 107* the head of one gland is seen with branches sprouting in five different directions Part of its duct is shown in *section 102*. *Section 98* shows part of another duct near its orifice and a second sublingual gland. The biggest development of the latter's head is seen in *section 100*, while the more lateral *section, 93*, shows the middle part of its duct with the formation of two main branches. We also find on this side but further back about five more lesser sublingual glands (see *sec. 73* and *46*).

FIG. 27. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 102

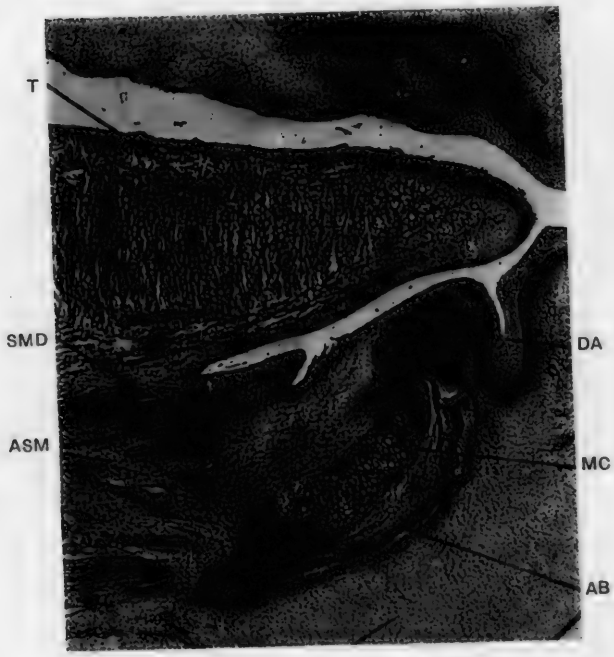

FIG. 28. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 93

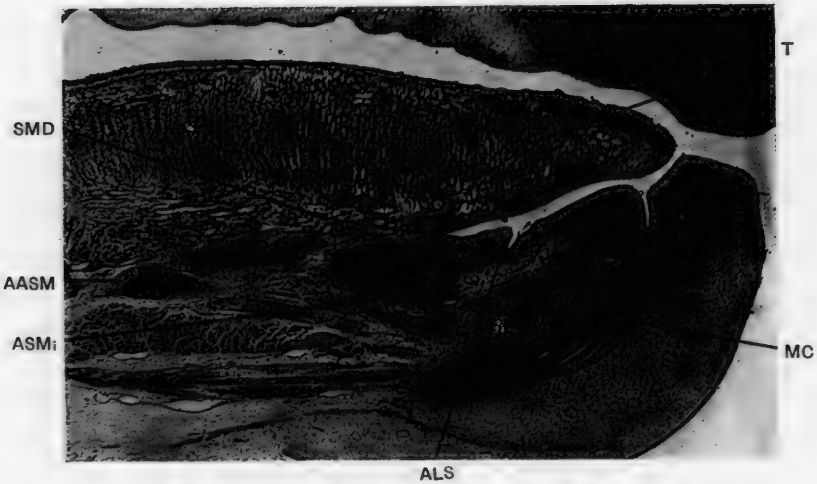

FIG. 29. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 98

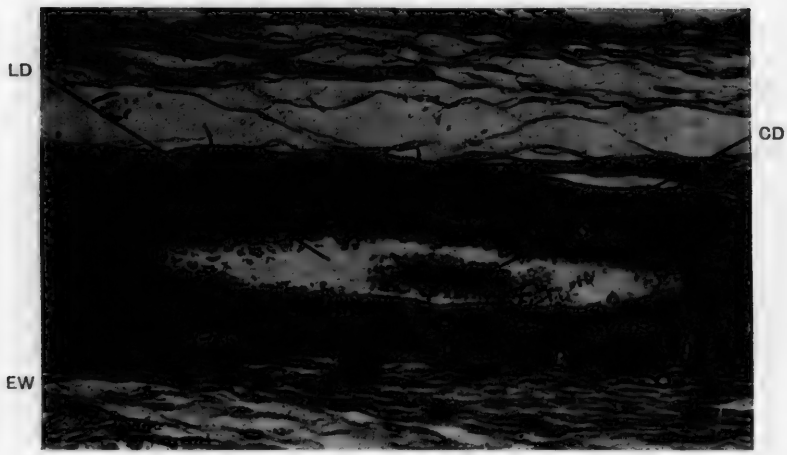

FIG. 30. EMBRYO 4. SPECIAL, LENGTH 47 MM., SECTION 80 (HIGH POWER OF SUBMAXILLARY DUCT)

FIG. 31. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 73

FIG. 32. EMBRYO 4, SPECIAL, LENGTH 47 MM.. SECTION 46

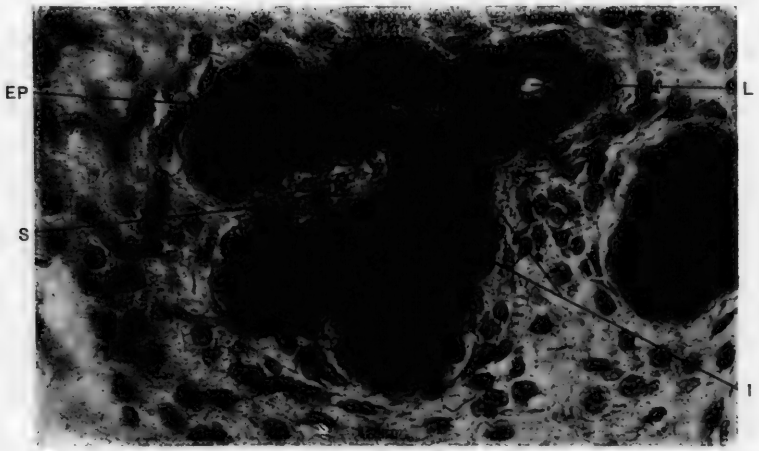

FIG. 33. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 62 (HIGH POWER OF END PIECES)

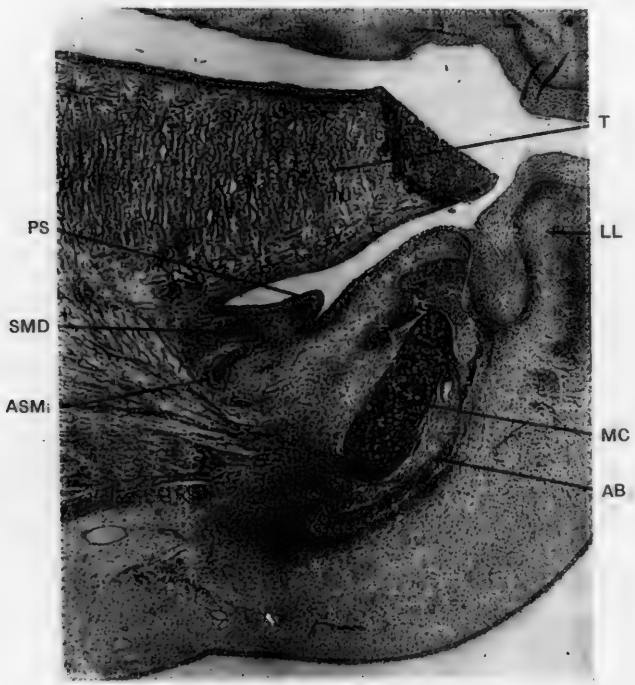

FIG. 34. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 154

FIG. 35. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 163

FIG. 36. EMBRYO 4, SPECIAL, LENGTH 47 MM., SECTION 249

Embryo 2, Special—length 52 mm.

The head of this embryo is cut in transverse frontal sections. I shall use only two of the series to show the relation of the various structures in a frontal plane. It is a little older than *embryo 4*.

Submaxillary glands. In *section 172* the submaxillary glands are seen to be of large dimensions extending well under the lower border of the inferior maxillary bone. Immediately over the superior part and mesial to the developing mandible and Meckel's cartilage we find the internal pterygoid muscle. The large ducts in the middle of the gland are well shown on the right side. They are made up of two rows of epithelium and a large lumen containing considerable debris and early secretions (see *fig. 39*). A few layers of connective tissue cells are arranged parallel with the main ducts to give them support and the immediate neighborhood is extremely vascular. Nerve fibres are also encountered occasionally. The end pieces are more or less peripherally placed, some having also already acquired a lumen; and it appears as if the mucous cells were in the making too, although no typical ones can as yet be seen. Smaller ducts and their branches are shown in cross and longitudinal sections. The connective tissue of the gland has become condensed and is distinctly different from the surrounding mesenchyma. *Section 20*, which is quite a good deal further toward the tip of the tongue, shows on the left side a cross section through the main duct of the submaxillary gland; and at its ventral side, slightly toward the inside, it also shows a section through a smaller duct, a secondary submaxillary duct. On the other side a ventral accessory gland can be found in serial examination.

Sublingual glands. No effort was made to secure photomicrographs of sublingual glands. Fragments of a smaller sublingual gland are visible however in *section 20*, their direction being ventral and toward the median line.

FIG. 37. EMBRYO 2, SPECIAL, LENGTH 52 MM., SECTION 20

FIG. 39. EMBRYO 2, SPECIAL, LENGTH 52 MM., SECTION 172 (HIGH POWER OF LARGE GLANDULAR BRANCH OF SUBMAXILLARY DUCT)

Embryo 5, Special—length, 62 mm.

This embryo had not been very well preserved, and the epithelium was in poor condition and could not be used for high power study. The sections from the median line to the first branches in the body of the submaxillary gland on both sides have been mounted.

Submaxillary glands. On one side we see the orifice of the submaxillary duct in *section 50*. The sections are cut at a slight angle to the median line, so that on this side we get long oblique sections through the ducts. Two ducts are given off from the same place, the dorsal one being the submaxillary duct. On the other side the submaxillary duct is given off alone.

Greater sublingual gland. This gland occurs only on one side and starts with the submaxillary duct in *section 50*. The ductus sublingualis major is smaller and shows a well-formed lumen. It runs along the ventral side of the submaxillary duct in *section 39*. Its diameter is only about half the size of the submaxillary duct. In *section 32* we see it curve more downward into the floor of the mouth. At the caudal end of this long duct, branches are given off that form an elongated gland body, the posterior extremity of which extends as far back as the submaxillary ganglion, over which the submaxillary duct passes to its destination.

Lesser sublingual glands. A large number are found on both sides. They are well-developed in the anterior part and near the middle line, where they show small branches all along their main ducts, from which the end pieces are developing. The ducts and branches show a lumen. On the side where there is no sublingualis major gland we find specially large lesser sublingual glands, one of which is shown in *section 157*. A number of sublingual glands of smaller size and not so well developed are seen further back in the lateral sections.

Anterior lingual glands. Two sprouts are seen growing into the substance of the tongue from the epithelium on its ventral surface. One is distinctly seen in *section 46*, and there is indication of another a little further toward the apex. The head of this glandular anlage is already of good size. Cross sections through it appear in a number of sections, the largest ones being in *section 39*.

Labial glands. These are formed in like manner from the basal cells of the epithelium of the lingual part of the lip. About eighteen or twenty sprouts were counted in all. Their heads are not quite as far developed as the ones of the anterior glands of the tongue.

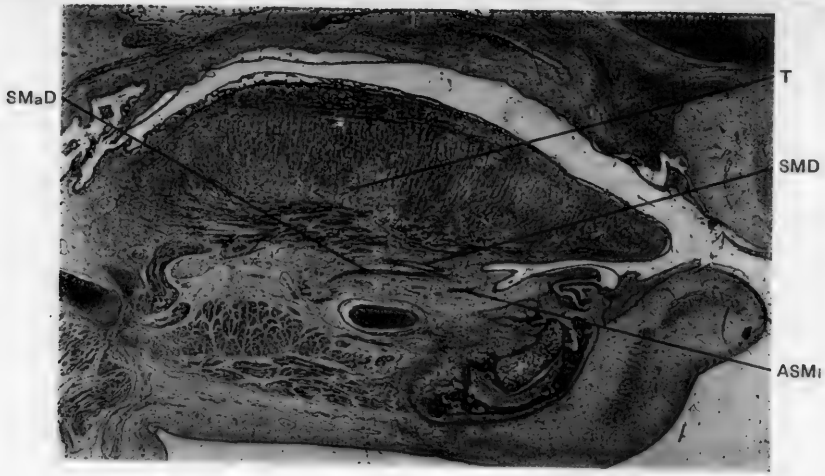

FIG. 40. EMBRYO 5, SPECIAL, LENGTH 62 MM., SECTION 32

FIG. 41. EMBRYO 5, SPECIAL, LENGTH 62 MM., SECTION 39

FIG. 42. EMBRYO 5, SPECIAL, LENGTH 62 MM., SECTION 46

FIG. 43. EMBRYO 5, SPECIAL, LENGTH 62 MM., SECTION 50

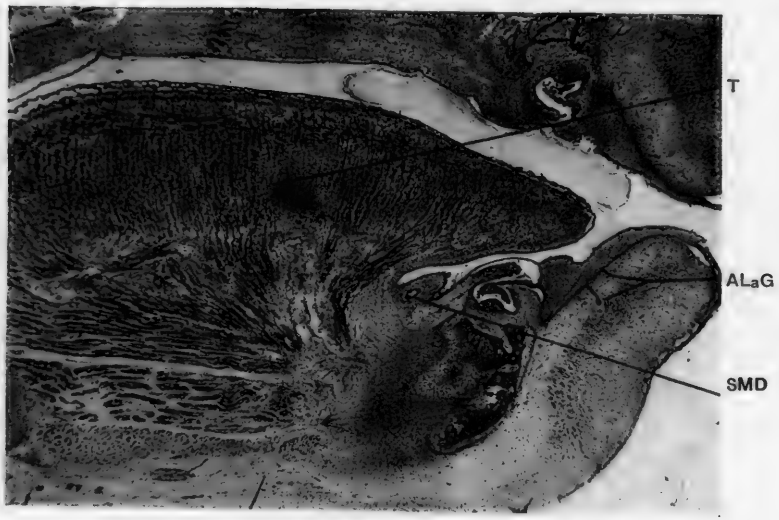

FIG. 44. EMBRYO 5, SPECIAL, LENGTH 62 MM., SECTION 82

FIG. 45. EMBRYO 5, SPECIAL, LENGTH 62 MM., SECTION 157

Embryo 6, Special—length probably 230 mm.

The anterior part of the lower jaw of this embryo was prepared for teaching purposes. The serial order of the sections was not preserved, so that a systematic study was not possible. Some of the sagittal sections of this very much older stage, however, show interesting progress in development.

Submaxillary glands. Cross sections through the submaxillary duct are seen in the sections. The submaxillary glands were not included in the specimen.

Lesser sublingual glands. These have developed very abundantly. Their ducts are simple and show small branches extending from their sides at right angles, each draining a small lobule made up of end pieces (see low and high power illustrations of *sec. 79*). The end pieces show the formation of a number of mucous cells.

Lingual glands. These are few in number, there being perhaps only two on each side. They seem to have small and short excretory ducts with many branches ramifying in a disproportionately large gland body. Mucous cells are abundant in the alveoli (see *sec. 40*).

Labial glands. There are a great many of these which have already developed to large size. Their ducts seem to describe tortuous curves before reaching the oral epithelium. They are seen in *section 79* and one gland with higher magnification from *section 58* is seen in *figure 49*. In this the lumen of the ducts extends far into the alveoli, where many mucous cells have already formed.

FIG. 46. EMBRYO 6, SPECIAL, LENGTH 230 MM., SECTION 79

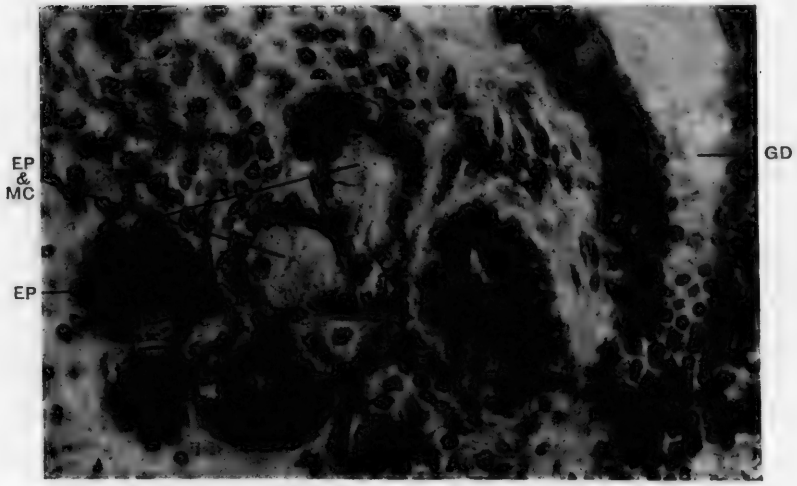

FIG. 47. EMBRYO 6, SPECIAL, LENGTH 230 MM., SECTION 79 (HIGH POWER)

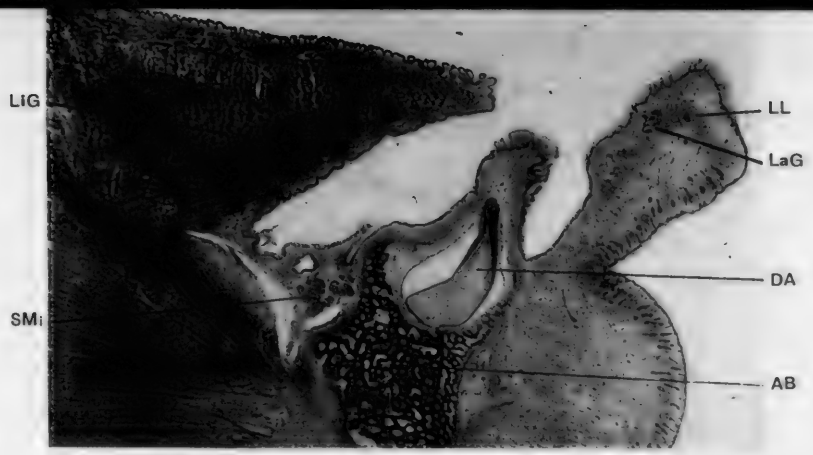

FIG. 48. EMBRYO 6, SPECIAL, LENGTH 230 MM., SECTION 40

FIG. 49. EMBRYO 7, SPECIAL, LENGTH 230 MM., SECTION 58 (HIGH POWER OF LABIAL GLAND)

CONCLUSIONS

The glands

The parotid gland. The younger embryos examined show that the anlage of the parotid gland is developed first. The anlage is quite definitely formed in the embryo of 10 mm. length.

The submaxillary gland. In the 10.2 mm. embryo an epithelial band is seen, which, in the writer's opinion, gives rise to the anlage of the submaxillary gland. In the transverse frontal sections through the embryos measuring 11, 11.5 and 11.7 mm. only the anlagen of the parotid gland can be seen. In the transverse frontal sections of the 12 mm. embryo the anlage of the submaxillary gland may be seen distinctly; in the 13.6 mm. embryo it has already developed into a large dumb-bell shaped sprout. Unfortunately, there were no embryos at my disposal cut in sagittal sections between 10.2 mm. and 18.1 mm. In the latter the anlage has already developed to a sprout of considerable size. Branches are first noticeable in the 20 mm. embryo, in which they have already acquired appreciable length.

Accessory and secondary lobes are first visible in an embryo of 22 mm. length.

Accessory and secondary glands occur rather frequently in all the embryos of 22 mm. or more in length which I examined. One or more such glands were found in four out of seven embryos, or 57 per cent (see *table 2*).

TABLE 2.

Data on the occurrence of accessory and secondary glands

EMBRYO NUMBER	SIZE	ACCESSORY GLAND		SECONDARY GLANDS	TOTAL	SUBLINGUAL MAJOR	REMARKS
		Ventral	Dorsal				
	mm.						
851	22.0	1	—	—	1	2	
1598	28.8	—	—	—	—	2	
1706	31.0	—	—	2	2	1	
290	32.0	—	—	—	—	—	Only one side sectioned
4	47.0	1	1	—	2	—	
2	52.0	1	—	1*	2	?	* Secondary duct seen in frontal section
5	62.0	—	—	—	—	1	

The epithelial sprout which forms the anlage of the submaxillary gland is given off from the lingual sulcus at the posterior end of an epithelial comb, just behind the lingual nerve, where the latter becomes infiltrated by the cells of the submaxillary ganglion. In older embryos the ducts first extend down ventrally, inclined toward the median line, and, after running a short distance, curve caudad and toward the side. On account of the general growth of the mouth the orifice is moved considerably forward and the duct becomes elongated. Soon after crossing over the submaxillary ganglion, through which the lingual nerve passes to enter into the tongue, it curves ventral around the mylohyoid muscle, where it gives off various branches. Here the anlage of the gland body is formed. It consists of proliferating epithelial sprouts surrounded by a capsule.

The accessory and secondary submaxillary glands form lobules resembling, except for their smaller size, the main gland. They are also surrounded by a capsule. The secondary glands are located anteriorly to the submaxillary ganglion and the mylohyoid muscle and have a duct of considerable length.

Greater sublingual (*Bartholinian*) *glands*. These glands develop at a still later period, the first well-defined anlage being seen in the 22 mm. embryo. They grow much more slowly than the submaxillary glands, but the ductus sublingualis major forms a lumen early. It is either given off from the submaxillary duct at its very beginning, or is formed separately from the epithelial comb directly anterior to and lateral from the orifice of the submaxillary duct. It may be present on only one side of the embryo. In two cases out of six (the 52 mm. embryo was not cut far enough forward to include the sublingual glands), it occurred on both sides, in two on one side, and in two cases it was entirely missing.

The lesser sublingual glands are also first found in the embryo measuring 22 mm. (*sec. 248*). In the younger embryos they are seen developing from the anterior part of the epithelial comb. Later we also find sprouts given off from the posterior part of this structure (embryo 31 mm., *section 343*). In older specimens buds are seen still further back, given off from the oral epithelium. The anterior ones develop earlier and grow to larger size than the latter. There may be between ten and twenty sprouts They form short branches on all

sides along their ducts. These in turn form secondary ducts, on which the end pieces or alveoli develop.

The anterior lingual glands are noticeable for the first time in the 62 mm. embryo and develop from sprouts which originate from the epithelium on the ventral surface of the tip of the tongue. They apparently start without any accumulation of epithelial cells or an epithelial ridge and are found on both sides of the median line. In the 62.0 mm. embryo two of these were found on each side (*sec. 46*). The epithelial cord, which is to be the duct, shows no lumen yet, but an enlargement has occurred at the end forming the anlage of the gland body (*sec. 39*). This is contrary to the theory of Schulte, who described this gland, "the apical gland of the tongue," as being derived from a sprout given off from the dorsal aspect of the submaxillary anlage. In *embryo 6* many mucous cells are seen in these lingual glands.

The labial glands develop simultaneously with the anterior lingual glands. In the 62.0 mm. embryo, from twenty to thirty sprouts could be found in the various sections through the lower lip. Here they are seen as epithelial cords with enlarged endings. A lumen has not yet formed, nor can any branching be seen at this stage. A later development is seen in *embryo 6*.

The development of the glandular epithelium and the reaction of the surrounding connective tissue

The development of the cellular elements of all these glands is in the main the same, except that the labial, anterior lingual and sublinguales minores remain comparatively simple in structure, while the sublingualis major and especially the submaxillary gland develop into highly compound forms.

Epithelium. The epithelial cells first accumulate before growing down into the mesenchyma and can be clearly differentiated, even at this stage, from the oral epithelium. The anlage soon takes on a more pronounced shape, so that a head and a cord can be distinguished. The sprouts at first grow perpendicular to the surface. The labial,

sublingual gland, and especially of the submaxillary, form long cords which bend toward the direction of their future destination. A differentiation of the epithelial cells is shown in a little later stage. The ones on the periphery grow more cylindrical and become arranged in a layer while the inner cells remain of the primitive rounded type. The head of the sprout shows a crowding of cells which soon gives rise to small buds from which the main branches develop. The duct now acquires a lumen and is lined with two or three layers of epithelium, the inner and outer layer being made up of more or less cylindrically shaped cells. The center cavity of the duct contains broken down cells and secretions (*fig. 30*). The lumen is probably caused by enlargement of the circumference of the duct, occurring from pressure due to secreted fluids (Chievitz, page 413). This lumen extends only as far as the main branches, which remain solid. Small buds grow out of the branches at right angles and from these, side branches are formed which give rise to several end pieces often arranged in a group or rosette around the terminal branch (see *fig. 33*). At first the appearance of the cells of the end pieces is uniform. Later a lumen is formed in the center and large cells of lighter color become apparent. These are mucous cells and are entirely filled with mucus. Their nuclei are pressed towards the periphery and become flattened out as the secretions accumulate (see *fig. 47*). They are first seen in the submaxillary gland of the 52 mm. embryo as cells which have attained a much larger size than the others. The nucleus is still in the center, however, the secretion not yet having accumulated. In the six months embryo mature mucous cells are seen in large numbers in the sublingual, anterior lingual and labial glands. Certain alveoli appear to show crescents, but this cannot be accepted as an assured observation, as it is almost impossible to say whether or not they are only young undifferentiated glandular epithelial cells.

Connective tissue. The mesenchyma surrounding the head of the submaxillary epithelial sprout shows a reaction at an early stage. The connective tissue cells accumulate, take on a concentric arrangement and are easily distinguished from the surrounding tissue. They

while toward the floor of the oral cavity it gradually passes over into the connective tissue. When branches are developed from the epithelial anlage of the gland they become surrounded by two or three layers of connective tissue cells arranged with their long axis parallel to the surface of the sprouts. Later, connective tissue fibres are formed which support the larger ducts and form so-called septa. Many vessels and occasionally nerve fibres are seen in the capsules of older specimens (see *fig. 39*), especially in the neighborhood of the main ducts and their larger branches.

The accessory and secondary lobes of the submaxillary gland also show formation of a capsule, which develops in similar manner.

The greater and lesser sublingual glands, as well as the lingual and labial glands, are not seen to develop a distinct capsule. Even in well-developed glands, such as are found in the six months old *embryo, 6*, there are only a few layers of connective tissue cells investing the periphery of the glands. The interlobular septa, however, are made up of dense connective tissue bundles which, at the periphery, give off a small number of fibres to surround the gland, the rest spreading into the adjoining connective tissue.

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EXPLANATION OF LEADERS FOR ALL ILLUSTRATIONS

AASM, Anlage of accessory submaxillary gland
AB, Alveolar process
AC, Anlage of capsule
AcSM, Accessory submaxillary gland
AL, Alveolar sulcus
ALaG, Anlage of labial gland
ALiG, Anlage of lingual gland
ALL, Anlage of lower lip
ALR, Alveolo-lingual region
ALS, Alveolo-lingual sulcus
AP, Anlage of parotid gland
AR, Alveolar ridge
ASM, Anlage of submaxillary gland
ASMa, Anlage of sublingualis major gland
ASMD, Duct of accessory submaxillary gland
ASMi, Anlage of sublingualis minor gland
ASSM, Anlage of secondary submaxillary gland
BM, Buccinator muscle
BS, Buccal sulcus
C, Capillary
CD, Contents of duct
DA, Dental anlage
DM, Digastric muscle
EB, Epithelial band
EC, Epithelial comb
EP, End pieces
EW, Epithelial wall
FA, Facial artery
GB, Glandular bud
GD, Glandular duct
GeM, Geniohyoid muscle
GhM Geniohyoglossus muscle
HyM, Hyoglossus muscle
IhM, Infrahyoid muscle
IL, Intermediate sulcus
IM, Internal pterygoid muscle
L, Lumen
LaG, Labial gland
LaGD, Labial duct
LD, Lumen of duct
LiG, Lingual gland
LL, Lower lip
LN, Lingual nerve
LS, Lingual sulcus
MA, Mandibular arch
MaM, Masseter muscle
MB, Main branch of duct
MC, Meckel's cartilage
Mdiv, Mandible divided
MM, Mylohyoid muscle
MuCe, Mucous cells
NS, Nasal septum
OC, Oral cavity
OE, Oral epithelium
OrG, Orbital gland
OSMD, Orifice of submaxillary duct
PP, Palatal process
PS, Plica sublingualis
S, Septum
SAbG, Superior alveobuccal gland
SAL, Sulcus alveolo-labialis
SG, Submaxillary ganglion
SM, Submaxillary gland
SMa, Sublingualis major gland
SMaD, Duct of sublingualis major gland
SMD, Submaxillary duct
SMi, Sublingual minor gland
SSM, Secondary submaxillary gland
SSMD, Duct of secondary submaxillary gland
StgM, Styloglossus muscle
StM, Sternocleidomastoid muscle
T, Tongue
V, Blood vessel
WG, Weber's gland

THE GROWTH OF PORTO RICAN BOYS, WITH SPECIAL REFERENCE TO THE RELATION BETWEEN THEIR STATURE AND DENTITION[1]

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Studies of growth usually give measurements of individuals based on their actual or "chronological" ages and not on their physiological status. The following relations of stature to physiological status, as defined by dentition, are based on plaster casts of the dental arches and on measurements of some three hundred and fifty school-boys of Utuado, Porto Rico, collected by Prof. Franz Boas in 1915. The method of treatment was suggested by Professor Boas.

It has been shown (1) that the observed characteristics of curves of growth may be explained as due to variations in the period of development, i.e., to accelerations and retardations. Since the stage of development of a child, at any period, depends on the previous acceleration or retardation of its growth, which affects the body as a whole, it follows that all measurements of the child must vary together; either all values must be increased beyond the average of its age by acceleration or all depressed by retardation. The more rapid the rate of growth, the greater is the effect of variation in period on all the measurements, that is, correlation between all measurements increases during the period of rapid growth and declines during the period of decreasing growth. The variation in period as expressed by a body measurement must be the variation of period at which a particular physiological status is attained. We find, therefore, a correlation between observed physiological status and body measurements. Such a correlation of pubescence to stature, weight, strength of the right hand, and mental development as indicated by school-standing, has been shown by Crampton (2); to head length and width, and to width of face, by Boas (3); and Deaver's data indicate a similar re-

[1] Reprinted, with changes, from the *American Anthropologist*, 1918, n. s., xx, pp. 37-48.

lation of pubescence to strength of the forearms and shoulder retractors, and to lung capacity (4). We should expect a similar correlation of physiological development as indicated by dentition with stature.

Crampton has demonstrated a correlation of dental development

TABLE 1

Number of deciduous teeth present in Porto Rican boys

AGE	CASES	UPPER JAW					LOWER JAW		
		Inner incisors	Outer incisors	Canines	First molars	Second molars	Canines	First molars	Second molars
7	25	7	18	24	22	23	20	19	19
8	44	7	16	31	33	36	24	30	29
9	38		3	23	17	24	12	15	17
10	74		10	31	19	47	18	28	30
11	65		2	16	11	27	9	7	21
12	56			7	3	10	2	4	10
13	81		2	8	3	9	2	4	11
14	84		1			1			1
15	60								

TABLE 2

Percentages of deciduous teeth present in Porto Rican boys

AGE	UPPER JAW					LOWER JAW		
	Inner incisors	Outer incisors	Canines	First molars	Second molars	Canines	First molars	Second molars
7	29	70	96	89	93	80	77	77
8	16	37	70	76	82	55	67	65
9		9	61	46	63	32	40	45
10		14	42	26	63	24	38	41
11		3	24	17	42	14	11	33
12			13	5	18	4	7	18
13		2	10	4	11	2	5	13
14		1			1			1
15								

with stature and weight. Among 934 New York boys, at a certain age individuals were taller and heavier in proportion to the number of permanent canines and second molars they had erupted (5). In this study the eruption of corresponding upper and lower teeth is considered as a single phenomenon. However, there is usually an interval of

about a year between their eruption; therefore, these results are somewhat invalidated. While the present series is smaller, about 350 individuals, the study has been extended to all the deciduous and permanent teeth.

TABLE 3

Number of permanent teeth present in Porto Rican boys

AGE	CASES	UPPER JAW							LOWER JAW				
		Inner incisors	Outer incisors	Canines	First bicuspids	Second bicuspids	First molars	Second molars	Canines	First bicuspids	Second bicuspids	First molars	Second molars
7	23	9	3		1		21		4			19	
8	44	37	15	9	12	4	44		16	5	1	43	
9	38	38	31	11	21	10	38	3	19	15	8	36	5
10	71	71	57	29	46	23	71	9	50	35	21	70	12
11	65	65	62	40	54	36	65	23	49	51	38	65	31
12	54	54	54	42	51	43	54	34	48	44	38	54	42
13	80	80	80	71	76	70	80	64	78	76	67	80	63
14	84	84	84	81	84	83	84	80	83	83	82	84	80
15	56	56	56	56	56	56	56	53	56	56	52	56	50
16	33	33	33	33	33	32	33	33	33	33	33	33	31
17	23	23	23	23	23	23	23	22	23	23	23	23	23
18	21	21	21	21	21	21	21	20	21	21	21	21	21
19	11	11	11	11	11	11	11	11	11	11	11	11	11

TABLE 4

Percentages of permanent teeth present in Porto Rican boys

AGE	UPPER JAW							LOWER JAW				
	Inner incisors	Outer incisors	Canines	First bicuspids	Second bicuspids	First molars	Second molars	Canines	First bicuspids	Second bicuspids	First molars	Second molars
7	46	13		4		93		16			84	
8	84	33	20	27	8	100		36	11	2	98	
9	100	82	30	54	28		9	50	40	20	95	12
10		80	41	65	32		12	70	49	29	99	17
11		96	62	83	56		35	75	79	58	100	47
12		100	77	94	79		63	88	81	70		77
13			89	95	87		80	98	95	84		79
14			97	100	99		95	99	99	98		95
15			100		100		95	100	100	93		90
16					97		100			100		94
17					100		97					100
18							96					
19							100					

Physiological periods for the Porto Rican boys may be obtained from the data on dentition. Tables 1 to 4 show the number of deciduous and permanent teeth present among a total of all possible cases of teeth of each kind: teeth, not individuals, are the units. Permanent teeth protruding beyond the gums to any degree were counted as erupted teeth. Any recognizable fragment of a deciduous tooth was counted. Recognition is difficult in plaster casts and mechanical causes operate more freely on the fragments than on permanent teeth; hence, the tables for deciduous teeth are not so smooth as for the permanent.

The data in tables 1 to 4 afford the basis for the calculation of the average ages and variabilities for the loss of the deciduous teeth and the eruption of the permanent teeth, as given in tables 5 and 6.

TABLE 5

*Average ages and variabilities for the loss of the deciduous teeth in Porto Rican boys**

	OUTER INCISORS	CANINES	FIRST MOLARS	SECOND MOLARS
Upper	7.8 ± 1.6	9.5 ± 2.5	9.1 ± 1.9	10.3 ± 2.1
Lower		8.4 ± 2.2	8.9 ± 2.2	9.2 ± 3.2

* Anterior-posterior lengths of permanent and deciduous upper teeth were incidentally obtained:

	mm.	*cases*
Permanent inner incisor	8.6±0.7	618
Permanent outer incisor	6.5±0.7	547
Permanent first bicuspids	6.7±0.5	158
Permanent second bicuspids	6.4±0.5	161
Deciduous inner incisor	6.1±0.4	16
Deciduous outer incisor	5.1±0.7	50

TABLE 6

Average ages and variabilities for the eruption of the permanent teeth in Porto Rican boys

	INNER INCISORS	OUTER INCISORS	CANINES	FIRST BICUSPIDS	SECOND BICUSPIDS	SECOND MOLARS
Upper		8.5±1.4	10.3±2.2	9.2±2.0*	10.7±2.0*	12.1±1.7
Lower	6.2±1.5	7.0±1.3	9.0±2.3	9.9±1.8	10.9±2.0	11.4±2.0

* Upper bicuspids appear earlier than the corresponding teeth of the lower jaw in a mixed series of 4,850 boys and girls collected by James and Pitts: *Proceedings of the Royal Society of Medicine*, 1912, v, p. 80; and in a similar series of about 4,000 boys and girls by Livy: *British Medical Journal*, 1885, ii, p. 241.

For comparison, we have data on the average ages and variabilities for the eruption of permanent teeth of the upper jaw (probably of Boston school-children) based on plaster casts collected by Dr. Walter Channing. These averages (6) are based on the number of children having permanent teeth among the total number of children, e.g., a child with one or both permanent canines was counted as a child with permanent canines. Individuals, not teeth, are the units.[2] The averages are not strictly comparable with the Porto Rican, since by this method slightly earlier average ages are obtained than by using the teeth as units. We have also separated first and second bicuspids on the same casts, with the results shown in tables 7 and 8.

TABLE 7

Number of upper bicuspids present on Channing's casts

AGE	BOYS			GIRLS		
	Cases	First bicuspids	Second bicuspids	Cases	First bicuspids	Second bicuspids
6	46	1		92	4	2
7	60	1		76	12	3
8	56	12	6	60	19	9
9	84	33	16	82	41	21
10	62	39	20	65	41	22
11	46	35	25	56	36	29
12	40	32	22	44	36	26
13	24	21	16	34	32	25
14	26	25	20	20	18	16
15				14	14	14

TABLE 8

Percentages of upper bicuspids present on Channing's casts

AGE	BOYS		GIRLS	
	First bicuspids	Second bicuspids	First bicuspids	Second bicuspids
6	2		4	2
7	2		16	4
8	21	11	32	15
9	39	19	50	26
10	63	32	63	34
11	76	54	64	52
12	80	55	82	59
13	87	67	94	74
14	96	77	90	80
15			100	100

[2] Information obtained from Dr. Clark Wissler.

The average ages and variabilities for the Channing series are shown in table 9.

As these figures stand, the Porto Rican boys appear to erupt their teeth as much as a year in advance of the Boston boys. However, the meaning of this difference is obscure, since Channing and Wissler found that a group of feeble-minded children erupted their canines and second molars a corresponding period in advance of the same Boston boys (7). (See table 10 and compare with table 9.)

TABLE 9

Average ages and variabilities for Channing's series

	INNER INCISORS	OUTER INCISORS	CANINES	FIRST BICUSPIDS	SECOND BICUSPIDS	SECOND MOLARS
Boys.....	7.5±1.4	9.5±2.1	11.2±1.4	9.4±2.2	11.4±2.9	13.2±2.0
Girls.....	7.0±1.6	8.9±2.1	11.3±1.0	9.5±2.5	11.2±2.9	12.8±1.6

TABLE 10

Average ages and variabilities of feeble minded children (Channing)

	CANINES	SECOND MOLARS
Boys.....	10.7 ± 1.4	10.9 ± 1.9
Girls.....	10.0 ± 1 7	11.8 ± 0.9

If there is a correlation between physiological status and body measurements, then, at a certain age, those individuals accelerated beyond the average dental stage of their age should show a greater average stature than the remaining individuals. For example, eight-year-old boys with permanent upper canines are more developed than their age-mates who lack these teeth; as accelerated individuals, the group with canines should have an average stature greater than that of the group without canines. Similarly, a group lacking deciduous canines should be taller than a group of the same age with these teeth.

In tables 11 and 12 are given the average statures and variabilities of boys, separated on the basis of the presence and absence of the deciduous teeth, and on the absence and presence of the permanent teeth, tooth by tooth.

These data, together with a few cases referring to teeth not tabulated, are averaged for corresponding values for the upper and lower

TABLE 11

Stature of Porto Rican boys with deciduous teeth present and absent

AGE	OUTER INCISORS		CANINES		FIRST MOLARS		SECOND MOLARS	
	Present	Absent	Present	Absent	Present	Absent	Present	Absent
				Upper jaw				
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
7	1141 ± 48	1139 ± 69						
8	1166 ± 35	1189 ± 61	1182 ± 53	1173 ± 57	1177 ± 41	1187 ± 85	1181 ± 49	1170 ± 74
9			1245 ± 40	1268 ± 48	1243 ± 39	1263 ± 47	1241 ± 44	1276 ± 36
10	1266 ± 103	1276 ± 60	1242 ± 59	1299 ± 65	1247 ± 40	1284 ± 72	1274 ± 63	1275 ± 75
11			1263 ± 47	1325 ± 53	1277 ± 74	1317 ± 48	1296 ± 65	1321 ± 50
12			1336 ± 66	1389 ± 75			1356 ± 86	1386 ± 72
13			1308 ± 84	1394 ± 77			1294 ± 109	1397 ± 71
				Lower jaw				
8	1195 ± 57	1155 ± 44	1195 ± 57	1155 ± 44	1182 ± 56	1168 ± 48	1178 ± 58	1176 ± 47
9	1241 ± 48	1260 ± 48	1241 ± 48	1260 ± 48	1241 ± 32	1261 ± 53	1252 ± 44	1253 ± 49
10			1253 ± 50	1281 ± 72	1242 ± 54	1294 ± 69	1260 ± 71	1284 ± 62
11			1235 ± 43	1317 ± 51	1265 ± 75	1311 ± 53	1281 ± 61	1319 ± 50
12							1383 ± 83	1382 ± 78
13							1307 ± 102	1398 ± 270

TABLE 12

Stature of Porto Rican boys with permanent teeth absent and present

AGE	OUTER INCISORS		CANINES		FIRST BICUSPIDS		SECOND BICUSPIDS		SECOND MOLARS	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present	Absent	Present
Upper jaw										
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
8	1165 ± 41	1213 ± 64	1188 ± 52	1145 ± 49	1176 ± 41	1186 ± 81	1181 ± 45	1157 ± 95		
9	1249 ± 23	1254 ± 48	1257 ± 42	1260 ± 47	1243 ± 39	1263 ± 47	1242 ± 41	1284 ± 36		
10	1264 ± 78	1279 ± 63	1251 ± 58	1308 ± 68	1248 ± 57	1289 ± 69	1270 ± 48	1285 ± 71	1269 ± 61	1342 ± 69
11			1284 ± 51	1326 ± 57	1280 ± 80	1317 ± 51	1297 ± 65	1320 ± 51	1305 ± 60	1321 ± 53
12			1341 ± 60	1409 ± 64			1356 ± 86	1386 ± 72	1352 ± 62	1397 ± 77
13			1317 ± 82	1394 ± 77			1334 ± 134	1395 ± 67	1338 ± 103	1400 ± 68
Lower jaw										
7	1109 ± 26	1174 ± 60								
8	1173 ± 40	1179 ± 57	1187 ± 57	1159 ± 48						
9			1245 ± 50	1264 ± 45	1238 ± 36	1267 ± 51	1249 ± 41	1265 ± 50		
10			1248 ± 48	1285 ± 73	1249 ± 57	1293 ± 70	1262 ± 62	1305 ± 76	1266 ± 56	1335 ± 70
11			1266 ± 55	1317 ± 52	1292 ± 65	1310 ± 54	1287 ± 61	1321 ± 49	1292 ± 58	1323 ± 51
12			1362 ± 74	1385 ± 79	1353 ± 81	1387 ± 78	1352 ± 73	1392 ± 78	1335 ± 76	1394 ± 75
13							1314 ± 96	1400 ± 70	1343 ± 79	1396 ± 80

TABLE 13

Stature of Porto Rican boys (in millimeters) based on all teeth (average of statures in tables 11 and 12, with additional cases)

AGE	UPPER JAW						LOWER JAW						UPPER AND LOWER JAWS	
	Permanent		Deciduous		Permanent and deciduous		Permanent		Deciduous		Permanent and deciduous		Permanent and deciduous	
	Absent	Present	Present	Absent	P. absent D. present	P. present D. absent	Absent	Present	Present	Absent	P. absent D. present	P. present D. absent	P. absent D. present	P. present D. absent
7	1142± 51	1147±61	1146±52	1134±56	1144± 51	1141±59	1138±52	1154±55	1144±55	1143±54	1140±53	1149±54	1142±52	1146±56
8	1178± 47	1181±60	1177±46	1182±61	1177± 46	1182±60	1181±51	1174±54	1182±55	1175±51	1181±52	1175±53	1179±49	1178±56
9	1249± 40	1259±46	1243±40	1260±45	1247± 40	1260±45	1248±42	1256±45	1249±43	1258±46	1249±42	1257±45	1247±41	1259±45
10	1262± 63	1283±68	1259±64	1280±68	1261± 63	1282±68	1259±57	1282±69	1252±60	1280±68	1257±58	1281±69	1259±61	1282±68
11	1294± 61	1316±55	1281±63	1317±54	1290± 62	1316±54	1286±59	1313±55	1267±61	1313±54	1281±60	1313±54	1286±61	1315±54
12	1353± 69	1387±73	1357±71	1383±73	1354± 69	1385±73	1349±73	1385±75	1319±74	1382±74	1341±74	1384±74	1348±71	1384±74
13	1324±105	1391±76	1308±93	1396±75	1319±100	1393±76	1314±88	1390±78	1251±45	1399±74	1292±80	1394±76	1303±90	1394±76

jaws at first separately, and finally together (table 13). This is in effect simply weighting the stature of each individual according to his dental pattern.

After the ninth year the average statures of the retarded and accelerated groups differ, the absolute difference increasing to the fourteenth year (see particularly the last two columns, table 13). These values show that there is a functional relation between stature and the physiological status defined by dentition.

For comparison, the upper bicuspids of boys and girls of the Channing series have been treated in the same manner with regard to stature and weight (tables 14 and 15). This smaller series gives affirmative results for both statures and weights.

TABLE 14

Stature (in millimeters) of children with upper bicuspids absent and present (Channing)

AGE	BOYS				GIRLS			
	First bicuspids		Second bicuspids		First bicuspids		Second bicuspids	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present
7					1162±44	1200±46		
8	1229±47	1244±73	1232± 53	1231± 60	1216±44	1216±43	1217± 44	1214± 44
9	1267±59	1282±54	1297± 66	1286± 47	1250±55	1292±84	1264± 61	1292±107
10	1334±68	1319±62	1310± 59	1339± 65	1296±67	1318±64	1311± 68	1312± 63
11	1373±73	1319±91	1348± 69	1319±103	1323±68	1351±75	1329± 80	1351± 67
12	1374±74	1399±84	1381± 83	1405± 86	1335±56	1423±73	1374± 80	1430± 67
13			1438±122	1433± 89			1448±118	1527± 56

TABLE 15

Weight of children with upper bicuspids absent and present (Channing)

AGE	BOYS				GIRLS			
	First bicuspids		Second bicuspids		First bicuspids		Second bicuspids	
	Absent	Present	Absent	Present	Absent	Present	Absent	Present
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
7					54.7± 7.1	58.2± 6.0		
8	54.8± 7.4	58.7± 5.2	55.3± 7.2	57.8± 6.2	56.0± 7.7	54.4± 5.2	56.1± 7.1	52.3± 4.6
9	60.0± 9.6	58.8± 7.6	57.7±10.3	60.8± 8.2	54.9± 5.9	60.2±10.0	56.1± 7.2	61.5±11.1
10	61.9± 6.9	62.6± 7.5	60.8± 6.4	65.7± 7.9	62.0± 8.8	63.2± 8.9	62.9± 9.1	61.4± 8.5
11	68.8±14.3	68.6± 7.3	66.2±11.3	70.8± 6.6	65.0± 8.1	64.7± 7.7	64.6± 7.9	65.1± 8.1
12	66.4±11.7	71.5±12.4	67.7± 3.0	73.2±12.3	65.2±10.9	77.3±12.7	73.2±16.1	76.0±10.8
13			76.3± 9.1	79.1±18.4			89.3±22.3	89.5±20.8

Having shown that variations in stature correspond to variations in the period of physiological development, we can obtain an insight into the character of the variations in period by considering each measurement as corresponding to the age to which it would belong according to the table of average statures for all boys and girls (table 16).

TABLE 16

Statures and weights of all boys and girls referred to in the preceding tables

AGE	PORTO RICAN BOYS		CHANNING SERIES					
			Boys			Girls		
	Cases	Stature	Cases	Stature	Weight	Cases	Stature	Weight
6			23	1131±38	52.1± 8.5	46	1126±43	51.3± 6.5
7	14	1144± 56	30	1165±60	53.6± 7.5	39	1168±45	55.3± 7.0
8	26	1179± 53	27	1232±53	55.6± 7.0	31	1216±43	55.5± 7.0
9	23	1254± 45	40	1273±57	59.5± 8.7	42	1271±73	57.5± 8.6
10	39	1275± 68	33	1323±63	62.3± 7.3	34	1310±65	62.8± 8.8
11	37	1311± 57	21	1332±89	68.7± 9.2	30	1340±73	64.9± 7.9
12	30	1381± 75	21	1394±81	70.7±12.3	22	1407±77	75.1±13.0
13	42	1386± 82	12	1434±98	78.2±15.8	16	1506±97	89.5±20.8
14	47	1468± 90	12	1552±85	88.1± 3.0	9	1541±99	99.9±30.7
15	32	1519±102				7	1599±53	108.0± 4.1
16	18	1571± 66						
17	14	1602± 62						
18	12	1627± 87						
19	6	1620± 45						

Confining our attention to the final values for Porto Rican boys (last two columns of table 13), we can interpolate in this table, for example, for a stature of 1303, which gives 10.8 as the age for the corresponding average stature.

The ages obtained from data for dentition and stature (table 17) probably differ more from the corresponding chronological ages than would ages obtained on the basis of stature alone.

At the beginning of the period of rapid increase in the rate of growth, the accelerated individuals must be growing at a higher rate than the retarded individuals of the same chronological age but who have not yet entered into the period of rapid growth. Conversely, at the end of the period of rapid growth, the accelerated individuals must grow

TABLE 17

CHRONOLOGICAL AGE	PHYSIOLOGICAL AGE	
	Permanent absent. Deciduous present	Permanent present. Deciduous absent
7	7.0	7.0
8	8.0	8.0
9	8.9	9.3
10	9.3	10.2
11	10.3	11.2
12	11.5	12.7
13	10.8	13.1

at a slower rate than the retarded. Consequently, at the beginning of the period, accelerated individuals must vary more than retarded individuals from the average of their ages and less at the end of the same period. We have compared below the variabilities of the retarded and accelerated groups of each age (table 18).

TABLE 18

AGE	RETARDED GROUP	ACCELERATED GROUP	DIFFERENCE
7	52	56	+ 4
8	49	56	+ 7
9	41	45	+ 4
10	61	68	+ 7
11	61	54	− 7
12	71	74	+ 3
13	90	76	−14

While the results are not marked, the accelerated group varies more than the retarded group at the beginning of the period of rapid increase of the rate of growth, but less at the end of the same period. From another point of view the increased variabilities in stature for both accelerated and retarded groups may be an expression of a different rate of development from that of dentition. If this is so, the greater the degree of acceleration or retardation of dental development, the greater will be the variations in stature (8).

These data show that there is a marked functional relation between stature and stage of dental development, boys physiologically advanced or retarded showing corresponding variations in both stature

and dentition. Variations in stature, aside from such as are due to heredity and perhaps to other causes, are then expressions of variations in the period at which certain stages of development are reached.

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COMPARATIVE STUDIES ON THE CURVE OF SPEE IN MAMMALS, WITH A DISCUSSION OF ITS RELATION TO THE FORM OF THE FOSSA MANDIBULARIS

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I. INTRODUCTION

In 1890 Spee described some peculiarities of the occlusion of the bicuspids and molars, which are closely related to the form, and especially to the inclination, of the fossa mandibularis and the manner of movement of the mandible, and which have an important bearing upon the efficiency of these teeth as masticatory organs. A free translation of his initial statement follows:

"If a curved line be drawn touching the summits of the buccal cusps of the upper or lower teeth from first bicuspid to third molar, it will more or

less accurately correspond to the arc of a circle with its convexity downwards. This curve varies in different individuals. If, in a skull with typical denture, it is continued in a projection of the jaw upon the vertical sagittal plane, it touches the anterior face of the articular surface of the condyle. This is the most ideal form. In the case of man, the center of this curve lies behind the crista lacrymalis posterior and on the line bisecting the horizontal plane passing through the orbit."

The curve thus formed has been called "the curve of Spee" or "the compensating curve," and was considered by Spee to have important relations to the mechanism of mastication.

Fick (1911) doubted the relation stated to exist between this curve and the movement of the lower jaw, but he did not give any evidence to substantiate his contention (see section viii). This view of Fick has, however, not been further examined by other investigators and the conclusion of Spee is therefore generally accepted in its entirety. Since the conclusion of Spee has a very important bearing on the mechanism of mastication, I thought it worth while to reinvestigate the curve of Spee and if possible to determine whether Fick's objection is in any way justified.

As a first step an attempt was made to determine the nature of the curve shown by various mammals when the line is drawn touching the summits of the buccal cusps of the bicuspids and molars. From the curve thus obtained, the variations in the degree of the curvature shown by different species of mammals were determined for the purpose of a comparative anatomical study. At the same time, the degree of the inclination of the fossa, the gnathic index, dental index, and the angle between the line of articulation and basio-nasal line, were all measured directly on the skulls of many mammals, in order to determine whether any of these are related to the formation of the curve of Spee; indeed, Spee himself considers that the inclination of the fossa and the gnathic index have such a relation. Finally, using these data, the relation of this curve to the masticatory movements of the jaws is discussed.

This work was begun in July, 1917, and completed in the earlier part of 1918 at The Wistar Institute of Anatomy and Biology. It gives me great pleasure to acknowledge my indebtedness to Dr. Greenman, Director of the Institute, for his generosity in permitting

me to study at the Institute, and in furnishing me with all the material and instruments necessary for the present investigation. Also I wish to express my thanks and gratitude to Dr. Turner and Dr. Hatai, for their kindness and interest shown me during the course of this investigation and in the revision of this paper.

II. MATERIAL USED IN THESE STUDIES

The skulls used for this study belong to the collection in the museum of the Wistar Institute of Anatomy and Biology, and had been prepared by the usual method for the purpose of exhibition. Nearly 120 skulls, representing several orders of mammals, and apparently of adult age, as shown by the presence of the well developed third molars, were available. On account of the difficulty in getting human skulls which show the ideal occlusion, only fourteen human skulls out of this series were utilized, though for the other orders of mammals, this selection was easier. In the cases of Porcus babyrussa, Lama huanacho, Cervulus muntjac, and Rhinoceros, however, I found only one specimen for each species.

In this paper I have followed the classification used by Brehm in his "Tierleben" (third edition, 1890). There are some orders of mammals which I did not study owing either to the difficulty in getting specimens, or because of the absence in them of the curve of Spee. The name, the locality (or race in the case of man), and the sex of each individual, as well as the museum catalog number, are given in table 1.

Examination of the material

Preliminary to the study of the curve of Spee, I attempted to determine the following two points on every skull used.

1. Whether or not the curved line, which is drawn touching the summits of the buccal cusps of the bicuspids and molars, would correspond to the arc of a circle with its convexity downwards.

2. If so, whether the extension of the curved line backwards touches the anterior face of the articular surface of the condyle?

I shall first present briefly the various methods employed for these determinations.

TABLE 1

A designation of the kinds and number of skulls used in these studies, and an indication of the museum number, locality (or race, in the case of man), and sex of each skull. Arranged according to the zoological order adopted by Brehm

SKULLS		ANIMALS	
Types	Museum number	Locality (or race)	Sex
PRIMATES:			
Homo (man)	800	?	?
	4237*	Negro	♂
		?	?
	5419	Eskimo	?
	4284	Negro	♀
	15700	Peruvian	?
	15803	Peruvian	?
	15863	Peruvian	?
	15779	Peruvian	?
	15689	Peruvian	?
	15613	?	?
	15640	Peruvian	?
	15774	Peruvian	?
	15586	Peruvian	?
Simia satyrus (orang utan)	5646	Borneo	♂
	2222	Borneo	?
	1563	Borneo	?
	2170	Borneo	?
	2172	Borneo	?
	7064	Borneo	?
	2223	Borneo	♂
Hylobates mülleri (gibbon)	6157	Borneo	♂
	690	Borneo	♂
	3666	Borneo	♂
	12074	Borneo	♂
	699	Borneo	♂
Macacus cynomolgus (macaque monkey)	1893	Borneo	♂
	1889	Borneo	♂
	1891	Borneo	♂
Semnopithecus femoralis (sacred monkey—India; hoonoomaŭn)	2989	Borneo	♀
	3801	Borneo	♂
	2657	Borneo	♂
	2925	Borneo	♀
	2920	Borneo	♀
	2923	Borneo	♂
	3000	Borneo	♂
	2660	Borneo	♀

* This specimen belongs to Dr. Stotsenburg.

TABLE 1—*Continued*

SKULLS		ANIMALS	
Types	Museum number	Locality (or race)	Sex
PRIMATES—*Continued*			
Nasalis larvatus (Kahau monkey)	2263	Borneo	♀
	2267	Borneo	♀
	1834	Borneo	♂
	2261	Borneo	♀
	6156	Borneo	♀
Macacus nemestrinus (macaque monkey)	5872	?	♀
	5861	?	♀
	5660	?	♀
	5860	?	♂
	5652	Penang	♀
CARNIVORA:			
Canis familiaris (dog)	6141	?	?
	6145	?	?
Felis leo (lion)	6201	?	?
	6196	?	?
Felis catus (cat)	6198	Texas	?
Procyon lotor (raccoon)	2278	?	?
	5970	?	?
	5976	?	?
	6006	?	?
	6008	?	?
RODENTIA:			
Fiber zibethicus (muskrat)	5902	Pennsylvania	?
	5921	Pennsylvania	?
	5884	Pennsylvania	?
	5916	Pennsylvania	?
	5883	Pennsylvania	?
	5918	Pennsylvania	?
	5915	?	?
	5903	?	?
	5908	?	?
	5889	?	?
Cavia cutleri (guinea pig)	5940	?	?
	5954	?	?
	5549	?	?
	5562	?	?
	5569	?	?
PERISSODACTYLA:			
Rhinoceros	4661	?	?
ARTIODACTYLA:			
Camelus bactrianus (bactrian camel)	5657	Zoological Garden, Philadelphia	♀
	6266	Zoological Garden, Philadelphia	♂

TABLE 1—*Concluded*

SKULLS		ANIMALS	
Types	Museum number	Locality (or race)	Sex
ARTIODACTYLA—*Continued*			
Lama huanacho (guanacho)	5632	Zoological Garden, Philadelphia	?
Rangifer tarandus (caribou)	5487	Alaska	♀
	5485	Alaska	♂
	5479	Alaska	♀
	5477	Alaska	♀
	5480	Alaska	?
	5484	Alaska	♀
	5475	Alaska	♀
Tragulus javanicus (musk deer)	6045	Borneo	?
	6091	Borneo	?
Cervulus muntjac (deer)	6182	Borneo	♀
Sus barbatus (boar)	2210	Borneo	?
	6163	?	?
	1569	Borneo	♂
	2853	Borneo	?
	6150	?	?
Porcus babyrussa (babirusa)	4773	Celebes Island	♂
Dicotyles sp. (peccary)	7451	?	?
	6202	?	?
	6207	?	?
	2199	Brazil	?
MARSUPIALIA:			
Didelphys marsupialis (opossum)	5971	?	?
	6095	?	?
	6025	?	?
	6273	?	?

Spee stated in his paper (1890) that, as the series of teeth in the adult human skull lies in a plane not deviating greatly from the sagittal plane of the skull (the smooth line *PQ*,—*figure 1*—connecting the summits of the buccal cusps of the bicuspids and molars having an angle 15 to 20 degrees to the sagittal plane, *OP*, of the skull), it follows that the relative position of the teeth does not deviate from their true relation if they are projected upon the sagittal plane with a large lens. He made photographs of skulls, setting the photographic plates parallel to the sagittal plane, and studied the curve on the photographs.

This method of Spee is open, however, to some criticism and, beginning with human material, I have employed the following projection method which seems to be better adapted for the purpose.

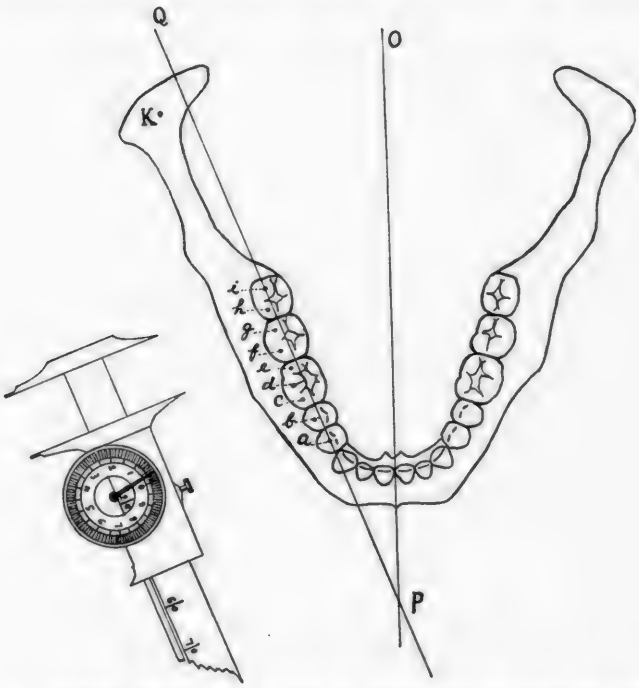

FIG. 1. DIAGRAM SHOWING THE PLANE OF PROJECTION AND ALSO THE FORM OF CALLIPERS USED FOR THE MEASUREMENTS

OP, projection plane used by Spee; *PQ*, projection plane used by the author; *a*, *b*, *c* . . . . and *i*, each buccal cusp from the first bicuspid to the third molar; *K*, middle point of the condyle.

The plane, on which the cusps are to be projected, has been so selected that it is perpendicular to the horizontal plane (on which the lower jaw[1] rests), and parallel to the line *PQ*—*figure 1*—which connects the buccal cusp of the first bicuspid and the disto-buccal

[1] For the preliminary examination of the curve of Spee, I used exclusively the lower jaw, because it is easier to manipulate in applying my method.

cusp of the most posterior molar. Instead of projecting the positions of each buccal cusp of the bicuspids and molars perpendicularly on this plane, I have measured the distances between each successive cusp and also the height of each cusp from the horizontal plane (on which the lower jaw rests). These two sets of measurements were plotted, taking the former for the abcissae and the latter for the ordinates. The desired curve was finally obtained by connecting the tips of the ordinates as shown in figure 2. This method of selecting the projection plane has some advantage when compared with that

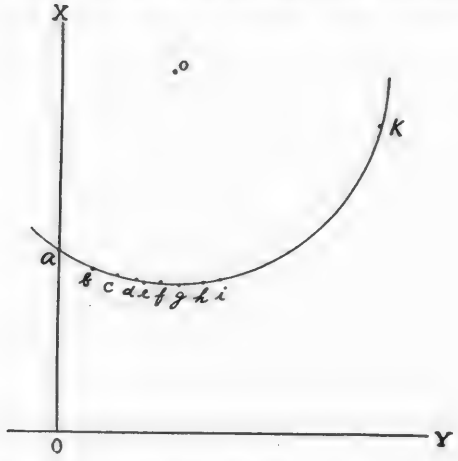

FIG. 2. SHOWING THE PROJECTION POINTS OF EACH BUCCAL CUSP AND THE MIDDLE POINT OF THE CONDYLE IN THE CASE OF THE ORANG UTAN

Specimen 2170, right. *OX*, ordinate; *OY*, abcissa.

of Spee, because the relative positions of the cusps of the teeth are better represented than when they are projected on the sagittal plane.

My method, however, is not entirely beyond criticism owing to the slight curvature of the dental arch, although the curvature of the dental arch at the region of the bicuspids and molars is insignificant, amounting to not more than 3 to 4 mm. between the arch and its chord, in the case of the human skull. Moreover, in skulls of some other mammals, e.g., the orang utan and the peccary, this curvature is practically zero. The method adopted by me does not distort the

normal relation to any great extent and I have therefore employed the method throughout the course of this investigation. For convenience of measurement the buccal cusps of the lower teeth and the middle point of the anterior face of the articular surface of the condyle have been designated individually from before backwards by letters of the alphabet, thus: *a* for first bicuspid, *b* for second bicuspid, *c*, *d*, *e* for first molar, *f*, *g* for second molar, *h*, *i* for third molar, and *K* for condyle (*fig. 1*).

There are several mammals to which the same designation cannot be applied on account of differences between their dental formula and that of man. Still another exception is found in the case of the opossum, owing to the unequal length in that form of the mesio-buccal cusp and disto-buccal cusp of the molar; the latter being two-thirds the length of the former. When the teeth are in occlusion, the disto-buccal cusps of the lower teeth are in contact with their antagonists, while the mesio-buccal cusps enter between the two cusps of the upper teeth. I therefore made the measurement only on the disto-buccal cusps, because in such instances it appears to me more reasonable to take the cusps which give contact with their antagonists, since these cusps alone have real importance in the process of occlusion. The lower jaw was placed on a straight line drawn on the table in such a way that all of the cusps of these teeth are on that line when seen from above. Then the distances between *a* and *b*, *b* and *c*, etc., were directly measured to 0.1 mm., the points of the callipers being held in a line parallel to the base-line on the table (*fig. 1*). As for the distance between *i* and *K*, I measured this holding the points of the callipers parallel to the projection plane (*QP*), but not necessarily parallel to the horizontal plane (or base-line). These measurements were entered as the abcissae on a sheet of paper which represents the projection plane.

The values of ordinates corresponding to the abcissal values were determined by the following method. The jaw was placed on the table, and the distance between the cusps and the table were measured to 0.1 mm. by sliding a cross-bar, which is attached to a rod standing perpendicular to the table, until it touched the top of the cusp. The distances for the cusps as thus measured were entered as ordinates on the same sheet of paper.

The position of K was determined by the following method. Since the distance between the points K and i had been already determined, as well as the vertical distance of the point K from the base-line, the position of K corresponds to the point of intersection made by the arc drawn by the radius iK (the point i being taken as the center of the arc) and by the vertical height of K along the abcissal line. Finally a curve was drawn passing through as many of the points as possible in order to determine whether or not the curve thus obtained is a circle. If the curve was a circle, the second question was whether or not this circle would pass through (or nearly through) the point K.

The foregoing method cannot be applied to the jaw of the muskrat on account of the difficulty in making the measurements on a specimen of such small size (nasion-basion diameter about 4 cm., the total length of the teeth[2] about 1.5 cm.). Therefore I made use of the following device: a small piece of paper (2.5 cm. by 1.0 cm.) was placed against the lateral side of the teeth and was rubbed with a pencil in order to trace the positions of the buccal cusps of the teeth. The positions of the cusps thus obtained were transferred to another sheet of paper by piercing these points with a needle. In order to determine the position of the point K, first the distance between the disto-buccal cusp of the first bicuspid and point K (on the plane of projection), and the distance between the disto-buccal cusp of the most posterior molar and point K, were determined. The point of intersection made by the two arcs, drawn with these two measurements as radii and the two corresponding points (first bicuspid and the most posterior molar) as the centers, is the desired point K.

Results of the examination

All the skulls I have examined may be arranged in four groups according to the form of the curve which was obtained by connecting the summits of the buccal cusps of the bicuspids and molars.

1. The group of skulls, in which the curved line corresponds to the arc of a circle, and touches at the same time the anterior face of the articular surface of the condyle or K. To this group belong man,

[2] The total length of the teeth means the distance from the mesial aspect of the first bicuspid to the distal aspect of the most posterior molar, all in situ.

Simia satyrus, Hylobates mülleri, Macacus cynomolgus, Nasalis larvatus, Semnopithecus femoralis, Macacus nemestrinus, Rhinoceros, Camelus bactrianus, Lama huanacho, Rangifer tarandus, Porcus babyrussa and Dicotyles (sp.).

2. The group of skulls in which the curved line corresponds to the arc of a circle but does not touch the anterior face of the articular surface of the condyle or *K*. To this group belong the muskrat and the opossum.

3. The group of skulls in which the curved line possesses several maxima, thus forming an undulating curve. Most carnivora, Tragulus javanicus and Cervulus muntjac belong to this group.

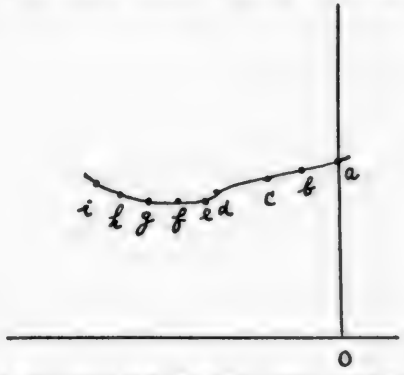

FIG. 3. SHOWING THE PROJECTION OF EACH BUCCAL CUSP OF THE BICUSPIDS AND MOLARS IN THE CASE OF THE RACCOON

The curved line connecting the points of projection shows an undulation

The existence of this kind of curve was evidently unnoticed by Spee, and it may be worth while, therefore, to describe it more in detail. As an example the curve given by the jaw of a Procyon lotor (raccoon), specimen 6008, is taken. The raccoon which belongs to the family of the Procyonidae, has the following dental formula:

$$I\,\frac{3-3}{3-3} \quad C\,\frac{1-1}{1-1} \quad PM\,\frac{3-3}{3-3} \quad M\,\frac{3-3}{3-3} = 40$$

As is shown in *figure 3* the line connecting the posterior half with the front half undulates owing to a slight dip, especially at the first

molar. This phenomenon is probably produced by the failure of the upper and lower bicuspids of the raccoon to occlude closely in the living specimen.

4. The group of skulls in which the arrangement is best represented by a straight line. This kind of curve is met with in the jaw of Sus barbatus (wild pig). Some individual variations were noted among the skulls belonging to this species. Among five skulls of Sus barbatus examined by me, specimens 2210, 1569, and 6150, have shown a slight curvature with its convexity downwards, while specimen 2853 has the convexity upwards.

III. SELECTION OF THE STANDARDS TO BE USED FOR THE PURPOSE OF COMPARING THE CURVE OF SPEE GIVEN BY VARIOUS MAMMALS

In the preceding section it was shown that in some species of mammals the projection of the buccal cusps of the bicuspids and molars upon a plane forms the arc of a circle. These points lie in the same cylindrical surface, as pointed out by Spee; and the line connecting them, when projected, has been designated "the curve of Spee" by subsequent writers. Since the precise form of the curve of Spee is not always the same, it has been my purpose to find some convenient standard by the use of which the differences can be expressed quantitatively. For this purpose Spee himself (1890) selected the length of the radius of his curve and the results of his observation are given by him in a chapter entitled: "Specielle Befunde an verschiedenen Gebissen." This method of comparison is valuable when the degrees of the curvature of the various curves of Spee are compared with each other. I have therefore followed the principle of Spee and determined the radius of the circle in order to determine the degree of curvature.

Since the curve of Spee is obtained by connecting the summits of the cusps of the bicuspids and molars, the length of the arc cannot be represented by the radius alone. The full form of the curve of Spee in any instance is determined by both its radius and the length of the arc. It is thus clear that in order to make a comparison of the curve of Spee as given by various mammals, we need, besides the radius, which represents the curvature at any point, also the length of the

arc. With this in mind, the number of degrees representing the angle which subtends a given length of the arc was determined by the following formula:

$$\text{Sin}\,\frac{A}{2} = \frac{\text{Chord}}{2r}$$

where A represents the angle and r the radius.

In the above formula the radius is given as the measure of the curvature and at the same time the length of the chord is given instead of the arc—the length of the chord being proportional to the length of the arc—and thus the former may be substituted for the latter. We may therefore consider that the angle A may be taken to represent both the length of the radius and the length of the arc. The angle A, called "the center angle," and its method of determination will now be presented.

IV. DETERMINATION OF THE LENGTH OF RADIUS

We have already stated that in the cylinder surface lies the part of the circle which passes through each cusp of the bicuspids and molars and the middle point of the anterior face of the articular surface of the condyle. It is possible to determine the length of the radius of any given circle or arc from the three points taken on the circumference by means of the formula on page 172. The three points a, h, and K, from the buccal cusps of the bicuspids and molars and the middle point of the anterior face of the articular surface of the condyle, would be preferable, since the distances between adjacent points should be as great as possible for the sake of exact measurements. I have however chosen the point h instead of the point i, because the point i in the third molar is not only absent in some cases, but also shows great variation. Speaking more precisely, the mesio-buccal cusp in the most posterior molar was chosen for the present purpose instead of the disto-buccal cusp. For measuring the constants α (ah), β (hK) and γ (aK) on the skull (*fig 4*), the directions which were given in the preceding section should always be followed. It must be emphasized here again that the circle, and the triangle which was formed connecting the three points, were both *projected upon the*

same plane. To obtain the radius (r) from the constants α, β, and γ, the following formula was used:

The radius (r) of the circle circumscribed about the triangle of area (t) equals $\alpha\,\beta\,\gamma/\,4\,t$. But from Hero's formula:

$$\text{Area } (t) = \sqrt[2]{S\,S_1\,S_2\,S_3}$$

$$\text{If } S = \tfrac{1}{2}\,(\alpha + \beta + \gamma), \text{ then}$$

$$S_1 = S - \alpha$$

$$S_2 = S - \beta$$

$$S_3 = S - \gamma$$

$$\therefore \text{ radius } (r) = \alpha,\ \beta,\ \gamma\ /\ 4\sqrt[2]{S\,S_1\,S_2\,S_3}$$

When the curved line did not touch the anterior face of the articular surface of the condyle (K), as in the case of the muskrat or opossum, some other point than K was taken, and the length of the radius obtained from the triangle as in the previous cases, or directly by the use of compasses.

The data obtained from these determinations are given in tables 2 to 18.

Tables 2 to 16 give, for each species, the values of α, β, and γ (measured directly on the skull); the length of radius (calculated on α, β and γ); the value of the "center angle" of the curve of Spee (calculated on the radius), of the angle of inclination of the fossa (measured directly on the skull), and of the articular basio-nasal angle (measured directly on the skull); also the gnathic index and the dental index, both measured directly on the skull and calculated for each individual. The name of each species is given at the head of the table. The arrangement of individual records within each table was made according to the diminishing value of the "center angle" of the curve of Spee. The numbers entered were all rounded and the mean values for each measurement are averaged according to the columns.

Table 17 gives for Primates the mean values of α, β, and γ, the mean length of radius of the circle, the mean value of the "center angle" of the curve of Spee, the mean value of the inclination angle of the fossa, the mean value of the articular basio-nasal angle, and the mean values of the gnathic and dental indices for each species. The arrangement

of species within the table was made according to the diminishing value of the "center angle" of the curve of Spee. The figures given in the table were all rounded.

Table 18 gives for Artiodactyla the mean values of α, β and γ, the mean length of radius of the circle, the mean value of the "center angle" of the curve of Spee, the mean value for the angle of the fossa,

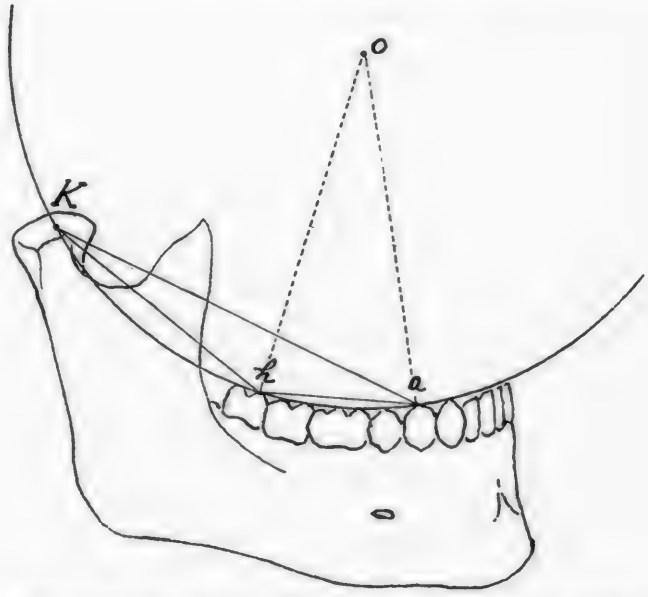

FIG. 4. DIAGRAM ILLUSTRATING THE CURVE OF SPEE AND ALSO THE "CENTER ANGLE"

K, middle point of the anterior face of the articular surface of the condyle; *a*, buccal cusp of the first bicuspid; *h*, mesio-buccal cusp of the third molar; *o*, center of the circle containing the curve of Spee; *aoh*, the "center angle."

the mean value of the articular basio-nasal angle, and the mean values of the gnathic and dental indices for each species. The arrangement of species within the table was made according to the diminishing value of the "center angle" of the curve of Spee. The figures given in the table were all rounded.

TABLES 2-16

A SUMMARY OF THE DATA OBTAINED FROM THE MEASUREMENTS OF THE SKULLS OF THE ANIMALS DESIGNATED IN TABLE 1

TABLE 2

Simia satyrus (orang utan)

NUMBER OF SPECIMEN	α	β	γ	RADIUS	CENTER ANGLE	INCLINATION ANGLE OF FOSSA MANDIBULARIS	ARTICULAR BASIO-NASAL ANGLE	GNATHIC INDEX	DENTAL INDEX
					degrees	*degrees*	*degrees*		
7064	4.6	7.4	10.1	5.5	48.8	26.5	25.5	151	57
2172	4.4	6.9	10.3	6.7	38.0	29.0	18.5	143	58
2170	4.1	7.3	10.3	6.6	36.6	30.5	22.8	148	55
5646	4.7	6.4	10.4	8.0	34.3	12.3	33.5	155	62
2222	4.3	6.6	10.2	7.4	34.2	17.8	20.5	140	53
1563	4.2	7.5	11.0	8.4	29.2	11.8	23.5	163	54
2223	4.6	7.6	11.6	9.5	28.2	20.5	31.5	159	60
Average.....	4.4	7.1	10.6	7.4	35.6	21.2	25.2	151	54

TABLE 3

Homo (man)

15640	3.8	5.4	8.5	6.0	36.6	31.8	33.5	103	49
15613	4.0	5.9	9.2	6.7	34.8	26.8	38.3	97	42
800	3.9	6.0	9.3	6.8	33.4	34.5	36.7	99	48
15774	3.6	4.9	8.2	6.9	30.4	42.0	42.5	105	48
15586	4.1	5.2	8.9	7.9	30.1	32.8	38.3	102	49
15863	3.6	5.7	8.8	7.1	29.4	33.5	34.0	99	47
5419	3.8	6.3	9.5	7.5	29.0	35.5	36.5	100	45
15803	3.9	5.6	9.1	8.4	27.2	28.8	35.8	105	46
——*	3.5	6.6	9.5	7.5	26.9	32.8	31.5	101	43
15689	3.5	6.2	9.2	7.8	26.0	43.0	35.8	98	41
15779†	3.5	5.6	8.6	7.0	26.0			98	
15700	3.3	5.7	8.7	7.5	25.5	41.5	36.5	104	45
4237	3.7	6.4	9.6	9.3	23.0	32.5	38.5	101	43
4284	3.6	5.8	9.1	9.4	22.1	27.5	40.0	100	43
Average.....	3.7	5.8	9.0	7.6	28.6	34.1	36.7	101	45

* This specimen belongs to Dr. Stotsenburg.

† The frontal portion of the occipital foramen of this specimen was lost, so that the determination of the articular basio-nasal angle and the gnathic and dental indices could not be obtained.

TABLE 4

Hylobates mülleri (gibbon)

3666	2.2	3.6	5.6	4.8	26.5	2.0	23.8	121	40
12074	2.1	3.3	5.2	5.2	23.3	9.0	29.0	122	41
699	2.1	3.4	5.3	5.3	23.3	3.0	28.3	118	39
690	2.1	3.2	5.2	5.8	21.5	7.0	26.3	119	39
6157	2.2	3.0	5.1	6.6	19.1	4.3	28.5	118	42
Average.....	2.1	3.3	5.3	5.5	22.8	5.1	27.2	120	40

TABLES 2-16—*Continued*

TABLE 5

Macacus cynomolgus (macaque monkey)

NUMBER OF SPECIMEN	α	β	γ	RADIUS	CENTER ANGLE	INCLINATION ANGLE OF FOSSA MANDIBULARIS	ARTICULAR BASIONASAL ANGLE	GNATHIC INDEX	DENTAL INDEX
					degrees	*degrees*	*degrees*		
1891	2.2	4.0	6.0	5.9	22.3	9.0	36.5	129	45
1893	2.3	3.9	6.0	5.9	22.0	8.8	31.8	138	48
1889	2.3	3.9	6.3	6.3	21.0	7.3	34.5	139	51
Average.....	2.3	3.9	6.0	6.0	21.8	8.4	34.3	135	48

TABLE 6

Nasalis larvatus (Kahaŭ monkey)

2261	2.5	3.9	6.1	5.9	24.8	4.8	33.5	120	50
1834	2.6	3.5	6.0	7.5	20.4	18.3	29.3	120	53
6156	2.8	3.3	6.0	8.3	19.2	0.0	34.5	127	54
2263	2.6	3.1	5.6	8.7	17.5	2.5	38.0	121	51
2267	2.6	3.2	5.6	8.7	17.1	4.5	36.8	123	53
Average.....	2.6	3.4	5.9	7.8	19.8	5.9	34.6	122	52

TABLE 7

Semnopithecus femoralis (sacred monkey—India; hoonoomaŭn)

2920	1.9	2.7	4.5	4.7	24.1	15.8	37.3	105	40
2657	1.9	2.8	4.6	4.5	22.6	14.0	34.8	107	41
2925	2.0	2.7	4.5	5.5	20.4	8.5	35.0	105	41
3000	2.0	2.7	4.6	6.4	18.4	2.0	38.5	110	44
2923	1.8	2.7	4.4	6.0	17.7	5.3	36.0	105	37
3801	1.8	2.7	4.5	6.1	17.5	21.8	37.0	105	40
2989	1.9	2.7	4.6	7.1	15.5	8.3	35.8	106	41
2660	1.8	3.0	4.7	7.3	13.9	7.0	35.0	105	39
Average	1.9	2.8	4.6	5.9	18.8	10.4	36.2	106	40

TABLE 8

Macacus nemestrinus (macaque monkey)

5660	2.9	4.0	6.7	7.5	21.5	−5.3	48.8	140	57
5652	2.8	4.5	7.1	8.5	18.8	12.8	45.5	153	60
5872	2.5	5.0	7.3	8.5	16.8	6.1	44.5	139	50
5861	2.7	4.0	6.7	12.3	12.5	0.5	46.3	134	55
5860	2.9	4.5	7.3	14.1	11.9	0.3	41.8	147	55
Average.....	2.7	4.4	7.0	10.2	16.3	2.8	45.4	143	55

TABLES 2-16—*Continued*

TABLE 9

*Fiber zibethicus (muskrat)**

NUMBER OF SPECIMEN	α	β	γ	RADIUS	CENTER ANGLE	INCLINATION ANGLE OF FOSSA MANDIBULARIS	ARTICULAR BASIO-NASAL ANGLE	GNATHIC INDEX	DENTAL INDEX
					degrees	*degrees*	*degrees*		
5889	1.6			3.4	27.7		21.5	132	33
5884	1.6			3.5	25.6		20.0	133	34
5902†	1.5			3.5	25.3				
5921	1.5			3.6	24.7		21.3	136	33
5903†	1.5			3.6	24.5				
5918	1.5			3.7	23.2		24.0	131	34
5916	1.5			3.7	23.1		19.8	145	34
5915	1.4			3.7	22.3		21.0	127	33
5908†	1.4			3.6	21.6				
5883	1.6			4.2	21.3		20.0	133	36
Average.....	1.5			3.6	23.9		21.1	134	34

* The degrees of inclination of the fossa are not given for this species because the temporo-mandibular articulation of this animal has no tuberculum articulare; consequently, the determination of the degree of inclination of the fossa would be of no value in this relation.

† The occipital bone including the occipital foramen were lost from these specimens, so that the angle of inclination of the fossa, the articular basio-nasal angle, and gnathic and dental indices could not be determined. The average values for each of these angles, therefore, were obtained from seven other specimens.

TABLE 10

Rhinoceros

4661	13.8	17.4	30.7	23.3	38.4	31.5	5.8	142	56

TABLE 11

Porcus babyrussa (babirusa)

4773	6.1	7.9	13.3	11.2	31.3	28.8	13.5	205	57

TABLE 12

Rangifer tarandus (caribou)

5479	7.4	9.2	16.4	14.6	29.5	13.0	21.3	214	65
5484	7.7	10.4	17.5	17.2	26.1	16.0	17.5	188	56
5477	7.7	9.3	16.5	17.2	26.0	17.8	24.0	211	62
5487	7.3	10.2	16.9	16.6	25.4	20.8	16.5	216	59
5485	7.1	10.5	17.0	16.3	25.2	14.5	26.0	217	54
5480	7.6	12.0	18.9	19.1	23.3	17.3	24.3	218	57
5475	7.4	9.6	16.6	18.9	22.6	10.8	25.0	230	66
Average.....	7.5	10.2	17.0	17.1	25.5	15.7	22.1	218	60

TABLES 2–16—*Continued*

TABLE 13

Camelus bactrianus (bactrian camel)

NUMBER OF SPECIMEN	α	β	γ	RADIUS	CENTER ANGLE	INCLINATION ANGLE OF FOSSA MANDIBULARIS	ARTICULAR BASIO-NASAL ANGLE	GNATHIC INDEX	DENTAL INDEX
					degrees	*degrees*	*degrees*		
5657	10.6	14.0	23.6	22.1	27.9	30.0	9.0	179	66
6266	10.2	13.7	23.3	25.9	22.7	19.0	13.5	176	66
Average.....	10.4	13.9	23.5	24.0	25.3	24.5	11.3	178	66

TABLE 14

*Dicotyles sp. (peccary)**

2199	5.9	4.3	9.9	10.5	32.6		36.0	126	42
6202	6.0	4.3	10.2	15.6	22.8		33.5	180	63
6207†	6.0	3.7	9.6	16.5	20.9				
7451	5.8	4.2	9.8	17.2	19.2		33.0	184	61
Average.....	5.9	4.1	9.9	15.0	23.9		34.2	163	55

* The degree of the inclination angle of the fossa is not given because the temporomandibular joint of this animal is a ginglymus.

† The upper incisors and both the first and second bicuspids were lost from this specimen, so that the line of articulation, and consequently, the inclination angle of the fossa, the articular basio-nasal angle, and the dental index, could not be determined.

TABLE 15

Lama huanacho (guanacho)

5632	5.5	10.5	15.4	13.6	23.4	67.5	18.8	171	46

TABLE 16

*Didelphys marsupialis (opossum)**

5971	3.2			6.3	29.4		16.0	189	73
6005	3.1			6.4	27.7		17.5	192	68
6273	3.1			6.6	27.7		17.0	198	72
6025	3.1			6.9	26.4		16.5	187	69
Average.....	3.1			6.5	27.7		16.7	192	71

* The degree of the inclination angle of the fossa was not given because the temporomandibular joint of this animal is a ginglymus

TABLES 17 AND 18

A SUMMARY OF THE MEAN VALUES GIVEN IN TABLES 2–16

TABLE 17

Primates

NAME OF SPECIES	α	β	γ	RADIUS	CENTER ANGLE	INCLINATION ANGLE OF FOSSA MANDIBULARIS	ARTICULAR BASIO-NASAL ANGLE	GNATHIC INDEX	DENTAL INDEX
					degrees	*degrees*	*degrees*		
Simia satyrus	4.4	7.1	10.6	7.4	35.6	21.2	25.2	151	54
Man	3.7	5.8	9.0	7.6	28.6	34.1	36.7	101	45
Hylobates mülleri	2.1	3.3	5.3	5.5	22.8	5.1	27.2	120	40
Macacus cynomolgus	2.3	3.9	6.0	6.0	21.8	8.4	34.3	135	48
Nasalis larvatus	2.6	3.4	5.9	7.8	19.8	5.9	34.6	122	52
Semnopithecus femoralis	1.9	2.8	4.6	5.9	18.8	10.4	36.2	106	40
Macacus nemestrinus	2.7	4.4	7.0	10.2	16.3	2.8	45.4	143	55

TABLE 18

Artiodactyla

Porcus babyrussa	6.1	7.9	13.3	11.2	31.3	28.8	13.5	205	57
Rangifer tarandus	7.5	10.2	17.0	17.1	25.5	15.7	22.1	218	60
Camelus bactrianus	10.4	13.9	23.5	24.0	25.3	24.5	11.3	178	66
Dicotyles sp.	5.9	4.1	9.9	15.0	23.9		34.2	163	55
Lama huanacho	5.5	10.5	15.4	13.6	23.4	67.5	18.8	171	46

V. DETERMINATION OF THE INCLINATION OF THE FOSSA MANDIBULARIS

It has been claimed by Spee that there exists a close dynamical relation between his curve and the inclination of the fossa, and a similar view has been held by some other authors. I have thought it desirable to examine this matter somewhat in detail.

To study the inclination of the fossa it is first of all important to decide just what portion of the fossa should be taken. Since the purpose of the determination of the inclination of the fossa is to provide data for the discussion of the relation between this inclination and the movement of the jaw, and also between the former and the curve of Spee, the area of articulation within the fossa should be used for the determination of the inclination. This area extends from the

middle portion of the posterior wall of the fossa to the anterior portion of the tuberculum articulare, and laterally from the lateral portion of the fossa to the anterior portion of the Glaserian fissure. Furthermore, this area presents its greatest width at the transitional portion of the anterior wall of the fossa to the tuberculum articulare.

It is evident that when the occlusion of the jaws is in the so-called "resting bite," the upper anterior portion of the condyle rests on the anterior wall of the fossa, that is, on the concavity of the area of articulation mentioned above, separated only by the meniscus (interarticular cartilage), while the posterior aspect of the articular surface

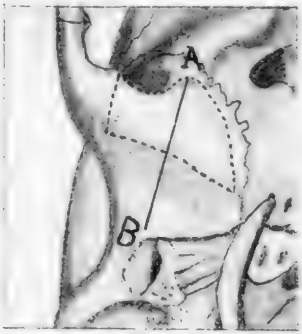

FIG. 5. DRAWING SHOWING, IN DOTTED LINES, THE AREA OVER WHICH THE UPPER ANTERIOR PORTION OF THE ARTICULAR SURFACE OF THE CONDYLE SLIDES

Showing the line *AB* drawn from the anterior margin of the area to the top of the processus postglenoidalis.

of the condyle is not in contact with the wall of the fossa. If the forward excursion of the lower jaw while in sliding contact starts from the resting bite, the condyle slips downward and forward to the crest of the tuberculum articulare in contact with the concavity of the area. In other words, in the case of sliding contact, the sliding between the condyle and the fossa by the forward excursion of the lower jaw is done principally in the concavity of the area.

It is now necessary to select a base line from which the angle of the inclination may be determined. Tomes and Dolamore ('01) selected a line parallel to the line drawn from the anterior nasal spine to the floor of the external auditory meatus, while Walker and Gysi

(1895) selected the line of occlusion.[3] I selected the line of articulation, i. e., the line which is tangent to both the morsal surface of the superior central incisors and the disto-buccal cusp of the upper second molar, because the line selected by Tomes and Doalmore does not seem to me to be related to the occlusion, and the line selected by Walker and Gysi has the disadvantage that it must be determined from the lower jaw.

My next attempt was to obtain the sectional surface along the median line of the fossa, as well as the line of articulation, projected on a sheet of paper. This was accomplished by the following method.

To obtain the sectional surface along the median line of the fossa I have followed the method adopted by Tomes and Dolamore. These authors however did not state the exact portion of the fossa taken, so in order to show the sectional lateral view of the fossa I endeavored to determine the total length from the anterior margin of the area of articulation to the top of the processus post-glenoidalis, which is a small conical process descending in front of the external auditory meatus (*fig. 5, A–B*). It was not however always possible to obtain the sectional view of the fossa by actual section from the museum specimens, so a modelling compound (dental) was advantageously used.

A line (*A–B, fig. 5*) was drawn with a pencil along the fossa of the skull from the anterior margin of the area of articulation on the tuberculum articulare through the fossa to the top of the postglenoid process and then there were marked also with a pencil two points on this line; one at the point where it crosses the posterior margin of the area, and the other at the point where the posterior portion of the crest of the tuberculum articulare passes into the anterior wall of the fossa. Then the fossa was filled with modelling compound under gentle pressure. As soon as the modelling compound hardened, it was removed and cut into two pieces along the pencil line, which had been transferred to it from the skull. One of these pieces was refitted to the fossa again exposing the lateral aspect of the cut surface. A line (*PQ, fig. 6*) parallel to the line of articulation was then drawn and a deep cut was made with a knife along this line. At the same time the positions of the two marks made before on the fossa were

[3] The line of occlusion is tangent to both the morsal surface of the lower central incisors and the disto-buccal cusp of the lower second molar.

transferred with a knife to the margin of the modelling compound as is shown in *figure 6* (*1* and *2*). The modelling compound was now removed from the fossa and the line of the fossa, including the two knife marks, made for the purpose of obtaining the angle of the inclination of the fossa, as well as the line of articulation, were stamped on a sheet of paper with the aid of painting ink. The value of the

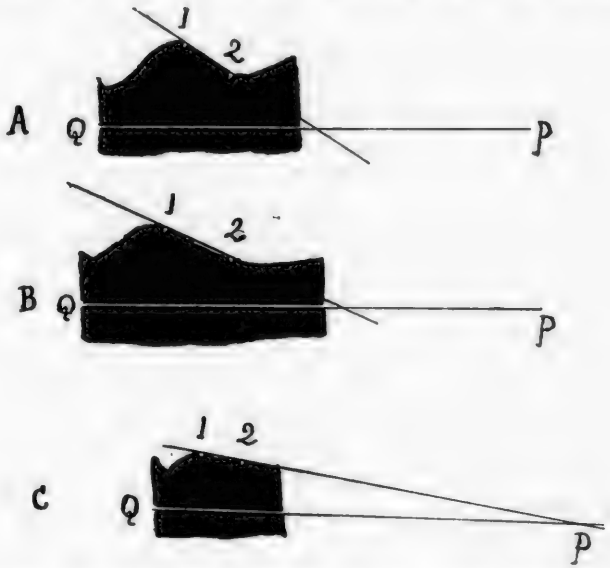

FIG. 6. THE CAST, SHOWING THE OUTLINES OF THE GLENOID FOSSA, OBTAINED BY THE METHOD OF THE AUTHOR (ACTUAL SIZE)

All of the fossae thus outlined were taken from the right side of the skull. The heavy line (*PQ*) is parallel to the line of articulation. The angle *PQ* is the angle to be measured. *A*, from the skull of man (Specimen 15613) angle 32 degrees; *B*, from the skull of orang utan (Specimen 7064) angle 24 degrees; *C*, from the skull of Hylobates (Specimen 12074) angle 8 degrees. *1* and *2* are two marks made with a knife, indicating the limits of the area.

angle between the line of articulation and the line which connects the two marks was obtained by the use of a protractor.

Even in the cases of the other animals this same method may be applied either directly or with some slight modification.

The results of these determinations are given in tables 2–16, except 9, 14, and 16. The averages are given in tables 17 and 18.

VI. DETERMINATION OF THE DENTAL AND GNATHIC INDICES

Dental index

"The dental index is the standard of measurement of the size of the teeth to the dimensions of the skull, and may be ascertained by means of the following formula, the length of the distance being marked out by the help of specially contrived calipers:

$$\frac{\text{The length of the teeth} \times 100}{\text{The basio-nasal line}}$$

The length of the teeth means the distance from the mesial aspect of the first bicuspid to the distal aspect of the most posterior molar, all in situ; the basio-nasal line is an imaginary line drawn from a spot on the middle line of the anterior margin of the foramen magnum of the occipital bone (the basion), to the junction of the nasal bones, with the nasal process of the frontal bone in the center of the lower edge of the nasal notch."

(Hopewell-Smith).

I have obtained the data on the dental index for the purpose of comparing the size of teeth of each animal, and at the same time to determine whether or not there exists any relation between this dental index and the curve of Spee. The values of the dental index thus obtained are given in tables 2 to 18.

Gnathic index

"The degree of projection of the upper jaw is expressed by the gnathic index, which represents the ratio of the distance between the 'basion' and the 'alveolar point,' to the distance between the 'basion' and the 'nasal point,' i.e., the point of junction of nasal and frontal bones on the middle line. Thus the gnathic index is obtained by ascertaining the value of the

$$\frac{\text{Basio-alveolar line} \times 100}{\text{Basio-nasal line}}$$"

(Hopewell-Smith).

My object in obtaining the gnathic index was to test the statement made by Spee that there is some anatomical relation between the prognathy of the jaw and the curve of Spee. The values for this index are given in tables 2 to 18.

VII. DETERMINATION OF THE ANGLE FORMED BETWEEN THE LINE OF ARTICULATION AND THE BASIO-NASAL LINE

As will be seen later, my own investigations fail to corroborate the statements made by Spee that there exists a close relation between the curve of Spee and the inclination of the fossa, but I have further attempted to find out what the curve of Spee means.

While examining many skulls, in which the curvature of the curve of Spee differs, one relation was found; that is, when the "center angle" was greater, the position of the fossa was correspondingly higher. Furthermore, the fossa and the occipital foramen have approximately the same relative distance from the horizontal plane. I attempted therefore to determine the situation of the occipital foramen in relation to other parts of the skull, and from the data thus obtained it was my hope to determine whether there is any relation between the position of the occipital foramen and the value of the "center angle." I found in the work of Topinard (1878) that Doubenton first determined the situation of the occipital foramen in relation to other parts of the skull. Afterwards Broca attacked the same problem, and proposed two methods. Thus, we have three methods for the determination of the situation of the occipitalforamen; namely, (1) in relation to the angle between the line drawn from the inferior border of the orbit to the opisthion, the opisthio-nasal line (Doubenton); (2) in relation to the angle between the occipital plane and the opisthio-nasal line (occipital angle of Broca); and (3) in relation to the angle between the occipital plane and the basio-nasal line (basilar angle of Broca).

After some practice with these three methods, I came to the conclusion that the last method suited my purpose best. However, to meet my purpose more completely, the occipital plane, which forms one side of the angle in the last method, was substituted by the line of articulation, because the latter line is directly related to the occlusion, while the former plane is not. Thus, I measured the angle ($A\ C\ N$)[4] between the line of articulation and the basio-nasal line by the following method.

[4] For convenience in description, the abbreviated form "articular basio-angle" is used in place of "the angle between the line of articulation and the basio-nasal line."

The skull was fixed with its basio-nasal line parallel to the horizontal plane by the use of a bar, and another bar was fixed in such a way that it was parallel to the line of articulation. The angle which was thus formed by the intersection of these lines at *C* was determined by means of a protractor. The data thus obtained are given in tables 2 to 18.

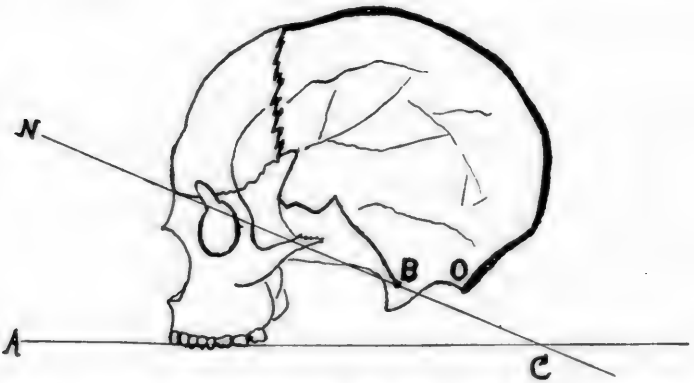

FIG. 7. THE ANTERIOR HALF REPRESENTS THE SKULL INTACT; THE POSTERIOR HALF REPRESENTS THE SKULL OPEN FOR THE PURPOSE OF SHOWING THE OCCIPITAL FORAMEN, AND ITS TWO MEDIAN POINTS; ANTERIOR (*B*) AND POSTERIOR (*O*)

O, opisthion; *B*, basion. The angle *ACN* is the articular basio-nasal angle

VIII. COMPARATIVE STUDY OF THE CURVE OF SPEE

The author's own data

Before beginning a discussion of the curve of Spee in various animals, it should be stated that the total number of skulls employed for this study was not large. Therefore, the absolute values of the data might be slightly different were the number increased, although it is my belief that any changes subsequently produced would not affect the general conclusions stated in this paper.

For convenience of description and of comparison, the material is classified according to the zoological order of the specimens. For reasons given in a previous section (III), the curves of Spee were compared with each other by comparing the size of the angle at the

center of the circle lying in the cylinder-surface or the "center angle," and the curvatures of the curves of Spee were compared with each other by comparing the lengths of the radii of the circles to which they belonged. When the data are arranged according to the diminishing values of the "center angle," the relations shown in table 19 are brought out.

From the data in table 19 it is clear that there is no general relation between the value of the "center angle" of the curve of Spee and the

TABLE 19

Values for the "center angle" in various species. Arranged according to the diminishing values for the "center angle"

NAME OF SPECIES	VALUE OF "CENTER ANGLE"
	degrees
Rhinoceros	38.4
Simia satyrus	35.6
Porcus babyrussa	31.3
Man	28.6
Didelphys marsupialis	27.7
Rangifer tarandus	25.5
Camelus bactrianus	25.3
Dicotyles sp.	23.9
Fiber zibethicus	23.9
Lama huanacho	23.4
Hylobates mülleri	22.9
Macacus cynomolgus	21.8
Nasalis larvatus	19.8
Semnopithecus femoralis	18.8
Macacus nemestrinus	16.3

zoological order to which a given species belongs. For example, in Simia satyrus (orang utan) the "center angle" amounts to 35.6 degrees; in Hylobates mülleri it is as small as 22.9 degrees. Both of these are primates. On the other hand, in the Rhinoceros, a perissodactyl, the "center angle" amounts to 38.4 degrees, and in Rangifer tarandus, an artiodactyl, it is 25.5 degrees.

Similarly, we do not find any close relation between the length of the radius of the curve of Spee and the order of mammals to which the species belongs. This fact is shown in table 20, in which the data are arranged according to the diminishing length of the radius.

TABLE 20

Data on the length of the radius of the curve of Spee for various species. Arranged according to the diminishing values for the radius

NAME OF SPECIES	RADIUS
	cm.
Camelus bactrianus	23.99
Rhinoceros	23.28
Rangifer tarandus	17.10
Dicotyles sp	14.95
Lama huanacho	13.56
Porcus babyrussa	11.22
Macacus nemestrinus	10.17
Nasalis larvatus	7.82
Man	7.55
Simia satyrus	7.43
Didelphys marsupialis	6.54
Macacus cynomolgus	6.02
Semnopithecus femoralis	5.94
Hylobates mülleri	5.50
Fiber zibethicus	3.64

Discussion

As to the physiological and anatomical significance of the curve of Spee and as to the relation of the curve of Spee to the other parts of the skull, Spee (1890) has put forward the opinions which were briefly summarized at the beginning of this paper, and it is now my intention to reconsider these statements of Spee in the light of my own data.

It is evident, from the data in tables 2 to 18, that there is no direct relation between the value of the "center angle" of the curve of Spee and the values of α, β, and γ, either among different individuals of the same species, or for different species of the same order. Since α has always a fixed relation to the total length of the teeth and γ to the length of the lower jaw in the same species, it must be conceded that both the total length of the teeth and of the lower jaw have no relation to the value of the "center angle" of the curve. Furthermore, since it is conceivable that the length of the lower jaw has a fixed relation to both the length and the size of the skull in the same species, we may conclude that there is no correlation between these

two measurements and the value of the "center angle" of the curve of Spee.

As was indicated in section VI, I measured the dental index (which represents the relation between the size of the teeth and of the skull), with the results given in tables 2 to 16. From these data I failed,

TABLES 21 AND 22

DATA PERTAINING TO THE DENTAL INDEX, AND THE LENGTH OF THE RADIUS OF THE CURVE OF SPEE. ARRANGED ACCORDING TO THE DIMINISHING VALUES FOR THE DENTAL INDEX

TABLE 21

Primates

NAME OF SPECIES	DENTAL INDEX	RADIUS
	degrees	*cm.*
Macacus nemestrinus	55	10.17
Simia satyrus	54	7.43
Nasalis larvatus	52	7.82
Macacus cynomolgus	48	6.02
Man	45	7.55
Semnopithecus femoralis	40	5.94
Hylobates mülleri	40	5.50

TABLE 22

Simia satyrus (orang utan)

Simia satyrus (orang utan):		
5646*	62	8.03
2223	60	9.46
2172	58	6.68
7064	57	5.51
2170	55	6.58
1563	54	8.38
2222	53	7.35

*Number of the skull of Simia satyrus.

also, to find any relation between that index and the value of the "center angle" of the curve of Spee. For example, in table 2, specimens 5646 and 2222 have nearly the same value for the "center angle" (the former 34.3 degrees, the latter 34.2 degrees) while the dental index of these specimens is different, the former being 62.0 degrees, and the latter 53.0 degrees. I also failed to find any relation between that index and the degree of curvature of the curve of Spee, which

latter can be inferred from the length of the radius of the curve, as may be seen from the tables. To illustrate the points just mentioned, the data in tables 21 and 22 were arranged according to the diminishing value of the dental index in orang utan and in the primates.

TABLES 23 AND 24

DATA PERTAINING TO THE GNATHIC INDEX, AND THE LENGTH OF THE RADIUS OF THE CURVE OF SPEE. ARRANGED ACCORDING TO THE DIMINISHING VALUES FOR THE GNATHIC INDEX

TABLE 23

Primates

NAME OF SPECIES	GNATHIC INDEX	RADIUS
	degrees	*cm.*
Simia satyrus	151	7.43
Macacus nemestrinus	143	10.17
Macacus cynomolgus	135	6.02
Nasalis larvatus	122	7.82
Hylobates mülleri	120	5.50
Semnopithecus femoralis	106	5.94
Man	101	7.55

TABLE 24

Simia satyrus (orang utan)

Simia satyrus (orang utan):		
1563*	163	8.38
2223	159	9.46
5646	155	8.03
7064	151	5.51
2170	148	6.58
2172	143	6.68
2222	140	7.35

*Number of the skull of Simia satyrus.

Spee states in his paper (1890) that, in general, the greater the radius of the cylinder-surface on which the occlusal line of the teeth lies, the bigger will be that animal, and the more prognathic the skull. "Der Radius des Cylinder-mantel, auf dem sie liegen, ist im Allgemeinen um so länger, je grösser das Tier, je prognater der Schädel ist." As will be seen from the tables, the results of my measurements show no correlation between the length of the radius, which measures

the degree of the curvature of the curve of Spee, and the gnathic index, which is taken to represent the degree of prognathy, neither within a species nor within an order. To illustrate these points the data in tables 23 and 24 were arranged according to the diminishing value of the gnathic index in orang utan and in the primates. The data in these tables show that the value of the "center angle" and the degree of curvature of the curve of Spee are independent of the size of the teeth or the size of the skull, or the degree of prognathy.

Relation between the "center angle" of the curve of Spee and the angle of the line of articulation to the basio-nasal line

We notice, from the data in table 17, that the average measurements given in the primates show a reciprocal relation between the value of the "center angle" of the curve of Spee and of the articular basio-nasal angle (the angle between the line of articulation and the basio-nasal line), if the data for man be omitted, i.e., the greater the "center angle" of the curve, the smaller will be the articular basio-nasal angle, or vice-versa. On the other hand, the average data for artiodactyla (table 18) show no such relation between these two measurements. Curiously enough, when similar data obtained from the different individuals of each species are compared, we do not find a reciprocal relation such as has just been described (see tables 2 to 16). This is true even when the different individuals compared are all of species of primates. Unfortunately, I possess very limited data for the other orders of mammals, and thus I am unable to determine whether or not there is, in other orders, a relation similar to that shown among the primates named in table 17.

If all available individual skulls belonging to the same species within the primates be examined, it will be seen that both the auditory meatus and basion (anterior border of occipital foramen) lie exactly or nearly on the same transverse diameter. As the fossa is always situated close to the auditory meatus, it is evident that the former has also a fixed relation to the basion in respect to the line of articulation. Since the curve of Spee touches the anterior face of the articular surface of the condyle by its backward extension, it follows that the "center angle" of the curve must be greater if the fossa lies

higher in the skull; and similarly, when the "center angle" is small, the fossa must lie lower in the skull of the same size. Combining these facts, it is conceivable that the relation of the basion to the line of articulation, or the articular basio-nasal angle, is related reciprocally to the "center angle" of the curve of Spee. Whether or not this explanation holds true for the skulls of different sizes cannot be definitely decided until more data are obtained, though it is my firm belief that such a relation is probable.

I stated before that the relation between the value of the "center angle" of the curve of Spee and of the articular basio-nasal angle is reciprocal, when different species of primates, with the exception of man, are arranged in series. In man the "center angle" is as large as 28.6 degrees and occupies the second position in the table, while the articular basio-nasal angle is not correspondingly smaller (36.8 degrees), but holds the sixth position (table 17). For the exceptional relation in man when compared with other primates, the following explanation seems plausible.

If a human skull is compared with the skulls of some other species among the primates, for example with the skull of an orang utan, it will be noted that the relative position of the auditory meatus and of the fossa is remarkably different; namely, when the line of articulation in both skulls is fixed parallel to the same horizontal plane, the auditory meatus of the human skull occupies a position slightly below the fossa, while on the contrary in the orang utan, it occupies a position slightly above it. This difference in the position of the auditory meatus and the fossa in the two species may be related to the factors which we now wish to discuss. If the skull of the orang utan is compared with that of man, it is evident that the latter shows a relatively greater development of the cranium. It therefore follows that in association with the greater growth of the cranial part, the occipital portion suffers a backward and downward extension, and as a consequence both the auditory meatus and the occipital foramen occupy slightly lower positions than in the orang utan. This difference in the relative position of the occipital foramen, and consequently of the basion, in the two forms seems to me to be a factor contributing to the enlargement of the articular basio-nasal angle in man, thus giving him an anomalous position in the table.

I am unable to suggest a satisfactory explanation for the absence of a similar relation between the "center angle" of the curve of Spee and the articular basio-nasal angle in the artiodactyla, or within the same species in the other orders. As a matter of fact, in a complicated structure like a skull, the anatomical relations which exist among the different parts are exceedingly complex, so that even the relation between the "center angle" of the curve and the articular basio-nasal angle may involve numerous factors which may be different in the different skulls. Again, the fact that in the primates the skulls show a reciprocal relation between the degree of the "center angle" of the curve of Spee and of the articular basio-nasal angle, if the human case be omitted, while in artiodactyla such a relation is absent, might be explained by further tests, but in the present state of our knowledge even a provisional explanation seems futile.

IX. RELATION BETWEEN THE FORM OF THE FOSSA MANDIBULARIS AND THE CURVE OF SPEE

As to the relation of the form of the fossa to the curve of Spee, Spee has given his opinion in different places in his paper (1890). I have compiled, below, his various statements so far as these relate to my own studies:

1. The development of the curve of Spee is dependent upon the presence of the tuberculum articulare.

In other words, the curve of Spee does not exist on a skull which has no tuberculum articulare.

2. In skulls possessing the curve of Spee, when the antero-posterior movement of the lower jaw takes place, the summits of the cusps of the bicuspids and molars of the lower jaw and the condyle move either on an arc of the same circle or on arcs of two circles which are homo-centric: the cusps on one circle, the condyle on the other.

We may deduce from this that the steeper the path of the condyle of the lower jaw during antero-posterior movement, the shorter will be the radius of the cylinder-surface, or vice-versa.

3. There is close relation between the curve of Spee and the sagittal movement of the jaw during mastication.

That is to say, we cannot recognize the curve of Spee on any skull which shows no sagittal movement of the jaw during mastication.

The results of my study apparently oppose these three conclusions by Spee. I present below the argument for my own views.

As to point one: Spee states that in rodentia and carnivora the curve of Spee is absent. In these forms the tuberculum articulare is also absent, while in the horse, Cervus elephas, Cervus dama, small monkeys and man, which show the curve of Spee, the tuberculum articulare is present. I have examined two species of rodentia, the guinea-pig (Cavia cutleri) and the muskrat (Fiber zibethicus). In the case of the guinea-pig the tuberculum articulare is absent and the animal does not possess the curve of Spee. In fact a line drawn connecting all summits of the buccal cusps of the bicuspids and molars is nearly a straight line. On the other hand, in the case of the muskrat, not only is the curve of Spee evident, but the degree of the curvature is considerable, as can be inferred from the small length of the radius of the circle (table 9), yet this animal does not possess the tuberculum articulare, as it should according to Spee.

In the case of carnivora, my observations agree with those of Spee that the skulls possess neither the curve of Spee nor the tuberculum articulare. It is well known that the temporo-mandibular joint in carnivora is quite different from that in most of the other mammals. For example, in Felidae the fossa is complete and therefore fits the form of the condyle (an interarticular cartilage being, however, interposed) with such accuracy that only a single motion is possible; consequently, in the process of opening the mouth, any part of the mandible must describe an arc of a single circle, of which the condyle is its center. The term "ginglymus" is used to describe such a joint, as was explained earlier.

All the carnivora examined by me possess the ginglymus joint, and the curved line touching the summits of the buccal cusps of the bicuspids and molars represents an undulating curve, as was described in section II in connection with the skull of the raccoon. Again, according to Spee, the tuberculum articulare is absent in all carnivora. However, in the cases of Didelphys marsupialis (opossum) representing the marsupials, and of Dycotyles sp. (peccary) representing the artiodactyla, I found that, although these animals possess a temporo-mandibular joint resembling that of carnivora, and consequently the tuberculum articulare is absent, nevertheless the curved

line of the bicuspids and molars corresponds to an arc of a circle. These findings lead me to reject the generalization of Spee that where the tuberculum articulare is absent, the curve of Spee is also absent.

As to point two: Before discussing this conclusion (2) by Spee, I present here my own results, which show the relation between the inclination of the fossa to the line of articulation and the length of the radius of the curve of Spee; also, the relation between the inclination of the fossa and the value of the "center angle" of the curve of Spee.

Throughout tables 2 to 8, 10 to 13, and 15, it will be found that there are no reciprocal relations between these two measurements among individuals belonging to the same species. For example, in table 3, specimen 15640 has the smallest length of radius, which amounts to 6.00 cm., while the inclination angle of the fossa is 31.8 degrees, the value of which is below the average (34 degrees) for the entire series. On the other hand, specimen 15689 has a radius of 7.8 cm., yet the corresponding degree of the inclination angle is 43 degrees. Condensed tables 17 and 18, which give the average values for the inclination of the angle of the fossa and the average length of the radius, for each species in the primates and artiodactyla, show also that there is no reciprocal relation between those two measurements among species belonging to the same order. For example, in table 17, Hylobates mülleri has the smallest length of the radius which signifies the possession of the greatest curvature, yet the greatest angle of inclination is given by man.

The data on the inclination of the angle of the fossa were obtained, as stated in section IV, from direct measurements on the prepared skull, thus disregarding the interarticular cartilage which is interposed between the condyle and the fossa. If therefore this cartilage were taken into consideration, the relation between these two measurements would be somewhat different. Fortunately, however, the meniscus in the fossa of man and of the other mammals is not so thick as to modify the general relations already obtained. In the case of man, for example, the meniscus in the backward portion of the fossa measures 3 mm. in thickness, that in the middle portion 1 to 2 mm., and it is interposed between the anterior face of the articular surface of the condyle and the articular surface of the fossa. Finally, the

forward portion measures 2 mm. in thickness and covers the tuberculum articulare.

Thus it is evident that, so far as my own observations go, the statement that the steeper the path of the condyle of the lower jaw during antero-posterior movement, the shorter will be the radius or vice versa, cannot be accepted.

The statement by Spee that the summits of the cusps of the bicuspids and molars of the lower jaw, and the condyle, will move on the same circle or on two homo-centric circles—the cusps on one circle, the condyle on the other—during antero-posterior movement, will now be discussed from the standpoint of mechanics. For convenience I shall make a brief statement concerning the mechanism of the antero-posterior movement of the lower jaw in man. Starting from the so-called "resting bite" of the jaw, we analyse the antero-posterior movement of the lower jaw into the following two components according to the motion of the incisors:

1. A downward and forward movement of the inferior central incisors (hereafter called the first part of the movement);

2. An upward and forward movement of the same (hereafter called the second part of the movement). In the first part of the movement, a point (j_i, *fig. 8*) on the morsal surface of the lower central incisors moves downward and forward parallel to the lingual surface of the upper central incisors (moving from point j_i to j_{ii}, *fig. 8*), because, following the protrusion of the jaw in the condition of sliding contact, the point (j_i) slides closely on the lingual surface of the upper central incisors. The remainder of the lower jaw, and consequently the center of the condyle, will move in the same direction, i.e., downward and forward parallel to the lingual surface of the upper central incisors. This first part of the movement has been called, by some, "parallel displacement (parallele Verschiebung)."

According to Eltner this first part of the movement is a "combined displacement (combinierte Verschiebung)" rather than a parallel displacement, because during protrusion the condyle rotates around the axis connecting the centers of the condyles, and at the same time rotates around the axis connecting the centers of the tuberculum articulare on both sides, while the lower jaw as a whole moves downward and forward. The condyle as a whole should therefore

not move parallel to the lingual surface of the upper central incisors, but its path should be a short arc of a circle. However, it seems to me that, even granting that in this instance the lower jaw moves on a circle, nevertheless the distance moved is but a few millimeters,

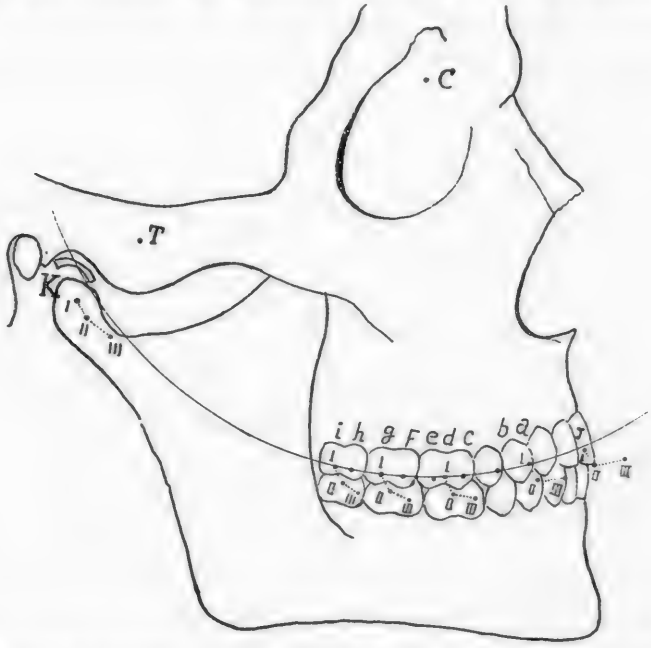

FIG. 8. DIAGRAM ILLUSTRATING THE DIRECTION OF THE MOVEMENT OF THE LOWER JAW IN THE FIRST AND SECOND PARTS OF THE MOVEMENT OF PROTRUSION, AND ALSO THE RELATION OF THIS MOVEMENT TO THE CURVE OF SPEE

●....●....●
I II III curve, showing the course of movement of each buccal cusp of the lower bicuspids and molars. (*j*): A point on the morsal surface of the lower incisors and (*K*) the middle point of the condyle. To avoid confusion in the drawing, curves are not given for each point, but only for *j*, *a*, *d*, *g*, *i*, and *K*. *T*.... transverse axis passing through each tuberculum mandibularis.

so that under these circumstances the path of the center of the condyle could be regarded as a straight line. My observations on the skulls which exhibit ideal occlusion induce me to conclude that all points in the lower jaw move downward and forward as a whole, thus producing the movement of the "parallel displacement."

In the second part of the movement, a point (j) on the morsal surface of the lower central incisors moves upward and forward, starting from the position of so-called "edge-to-edge bite" (from j_{ii} to j_{iii}), and at the same time the center of the condyle moves forward and downward along the articular surface of the tuberculum articulare (from K_{ii} to K_{iii}), so that the lower jaw as a whole rotates slightly around the axis represented by the line connecting the centers of the two condyles. This second part of the movement represents a combined displacement.

It appears therefore that the antero-posterior movement of the lower jaw in the state of sliding contact is a "parallel displacement" in the first part, and a "combined displacement" in the second part, of the movement; so that when the lower jaw is protruded, starting from the resting bite, or is retracted, starting from the position of protrusion, it might move either along a curve touching the summits of the buccal cusps of the bicuspids and molars (the curve of Spee), or along another curve parallel to this. But, in general, the direction along which the lower jaw moves is downward and forward in the first part and upward and forward in the second part; and thus, although the condyle or the points near it move, in the first part, nearly parallel to the curve of Spee, yet the course of the anterior portion of the jaw, or that further away from the condyle, deviates from the curve of Spee, the degree of deviation being proportional to the distance from the condyle.

The above relation may be seen clearly from *figure 8*. The line K_i–K_{ii} along which the condyle moves during the first part of the movement is nearly parallel to the curve of Spee, while the line a_i–a_{ii}, b_i–b_{ii} etc., along which each cusp moves during the first part, diverges from the curve of Spee, the degree of divergence being smaller as the condyle is approached. Moreover, the curve of K_i–K_{ii}–K_{iii}, a_i–a_{ii}–a_{iii}, b_i–b_{ii}–b_{iii}. etc., or successive positions occupied by the moving condyle or cusps during the first and second parts, is neither a portion of the curve of Spee nor of a circle homo-centric with it, as is shown in *figure 8*.

Finally, in the case of man, it is possible in some instances to slide the lower jaw antero-posteriorly some distance while in contact with the upper jaw. Such a movement of the lower jaw is, however,

possible only for a short distance, because anteriorly the morsal surface of the lower central incisors strikes the lingual surface of the upper central incisors at once, and posteriorly the head of the condyle strikes the processus postglenoidalis of the fossa at once. The maximum distance along which the lower jaw can travel is about 1 to 2 mm. Therefore, even if we grant that the jaw moves antero-posteriorly along the curve of Spee, it is highly improbable, on account of the short distance of such a movement, that the antero-posterior movement of the jaw has any relation to the curve of Spee, and consequently the existence of the curve of Spee is not associated with any greater efficiency in mastication.

During the course of this investigation it was found that there are some cases in which the jaw cannot perform an antero-posterior movement such as that just described, owing to the form of the teeth or of the temporo-mandibular joint; nevertheless, the presence of the curve of Spee is evident. For example, Simia satyrus, Hylobates mülleri, Macacus cynomolgus, Nasalis larvatus, Semnopithecus femoralis, Macacus nemestrinus, et. al, cannot perform such antero-posterior movements owing to the form of the teeth; in other words, the teeth of these mammals show ideal occlusion and thus there is no room for such antero-posterior movements when the jaws are in contact. Furthermore, Dicotyles sp., the peccary, and Didelphys marsupialis, the opossum, have a temporo-mandibular joint which is "ginglymus" as already stated, and for this reason they cannot perform such antero-posterior movements at all. Nevertheless in all these mammals the curve of Spee is unmistakably present.

Fick (1911) also opposes the conclusion of Spee for a reason similar to my own, namely, that the distance within which the lower jaw moves antero-posteriorly is too short. Furthermore, he states that when the rotation of the lower jaw takes place around the horizontal axis represented by the line which connects the middle of each orbit, the "coincident sliding (kongruentes Schleifen)" of the total occlusal surface of the teeth does not occur, because the projection of the teeth forms an arc not only upon the sagittal plane, but also upon the horizontal plane, so that when the lower jaw moves antero-posteriorly the occlusal surface of the bicuspids and molars does not slide coincidently, but the sagittal aspects of the teeth only slide by each other.

As to point three: Spee (1890) stated that the curve of Spee is found in those classes of mammals in which the tuberculum articulare is present, and that in the same animals the antero-posterior movement of the lower jaw is possible. As examples Spee gives the names of the following animals: horse, Cervus elephas, Cervus dama, small monkeys and man. To these I can add the names of the following animals: Simia satyrus, Camelus bactrianus, and Lama huanacho. Whether or not the antero-posterior movement of the lower jaw is possible for these animals, I am unable to state from my own investigation. Studies have been published in regard to this question in some of these animals, by others, however. Descriptions of the movement of the lower jaw during mastication have been given by Meyer (1865) and by Krabbe (1892). The most entensive observations on this subject are found in the laborious and exhaustive work of Lubosch (1907). The following account is based on the work of Lubosch, unless otherwise stated.

It will be advantageous to discuss the motion of the lower jaw in terms of the following three movements; opening, lateral and antero-posterior movements. In *marsupialia* and *carnivora*, the lower jaw performs mastication principally by the opening movement (especially the hinge movement) supplemented by a little lateral movement. In *perissodactyla*, besides the opening movement, both the antero-posterior movement and the lateral movement occur, the former however being much greater than the latter. In most *artiodactyla*, besides the opening, the movement of the lower jaw is principally lateral, although in some, e.g. pig and hippopotamus, the principal movement is antero-posterior with a little lateral movement. In *rodentia*, besides the opening movement, the principal movement is antero-posterior.

The description of the movements of the lower jaw just given reveals at once the fact that, despite the lack of antero-posterior movement during mastication, the curve of Spee is present in most of the artiodactyla (Lama huanacho, Rangifer tarandus, Camelus bactrianus, etc.) and in the marsupialia (opossum). Furthermore, in the pig, guinea-pig, and rodent, in which the movement of the lower jaw is principally antero-posterior, the line drawn touching the summits of the cusps of the bicuspids and molars does not represent the curve

of Spee, but is a straight line (see section II). We thus see that, in some of the mammals, the curve of Spee is found irrespective of the presence or absence of the antero-posterior movement of the lower jaw during mastication. It naturally follows that the close relation said, by Spee, to exist between the curve of Spee and the antero-posterior movement of the lower jaw, cannot be accepted without modification.

From the above it is clear that the statements made by Spee that there is close relation between the curve of Spee and the form of fossa, or between the curve of Spee and the antero-posterior movement of the lower jaw during mastication, cannot be accepted, whether we consider them from the standpoint of the mechanism of mastication or from actual tests made on the skull. Moreover, it is clearly indicated by this series of facts that the movements of the lower jaw during mastication in all animals named by Spee, as well as those studied by me, are not the antero-posterior movement only, but rather a mixed motion resulting from a combination of the three components which have been recognized. It follows, therefore, that, in the animals in which the curve of Spee exists, the teeth do not have any greater efficiency as a masticatory organ than in those animals which do not possess the curve of Spee.

It may be pointed out that, although the curve of Spee is often called "the compensating curve" under the erroneous impression that it compensates the movement of the jaw during mastication, yet, as I have already indicated in the preceding section, such compensation, in the sense of Spee, does not take place, and for this reason the use of the term should be discontinued.

X. SUMMARY

The main results of the present investigation are indicated in the following findings:

1. The line touching the summits of the buccal cusps of the bicuspids and molars was carefully studied on the skulls of numerous mammals. According to the nature and form of this curved line, three types may be distinguished; namely, (a) a curved line which corresponds to the arc of a circle with its convexity downwards (the

curve of Spee); (b) a curved line which, possessing several maxima, resembles an undulating curve; and (c) a type which is best represented by a straight line. The first type may be further divided into two kinds; one in which, in its backward extension in the projection plane, the curved line touches the anterior face of the articular surface of the condyle; another, in which the curved line does not do this.

2. The length of the radius of the circle of which the curve of Spee is a part was selected as a standard for comparison of the curvature of the arc, and the "center angle" which subtends a given length of the curve, was chosen as the standard in comparing the curve of Spee in different mammals. From the data obtained by these two kinds of measurements in several orders of mammals, the following results were calculated.

Of the primates examined, Macacus nemestrinus has the longest radius (10.17 cm.), Hylobates mülleri has the shortest radius (5.50 cm.), and man takes an intermediate position, having a radius of 7.55 cm. Of the artiodactyla, Porcus babyrussa has the shortest radius (11.22 cm.), while Camelus bactrianus has not only the longest radius (23.99 cm.) in this order, but also the longest among all the mammals examined.

In the case of the "center angle," the following relations were found: Among the primates, Simia satyrus has the greatest angle (35.6 degrees), Macacus nemestrinus the smallest (16.3 degrees), while man with 28.6 degrees occupies an intermediate position in the order. Among the artiodactyla, Porcus babyrussa has the greatest angle (31.3 degrees), and Lama huanacho the smallest (23.4 degrees). Rhinoceros was found to possess the greatest angle (38.4 degrees) among all the mammals examined.

3. Neither the curvature of the curve of Spee nor the "center angle" of the curve increases or decreases regularly according to the zoological order to which the animal belongs.

4. Neither the curvature nor the magnitude of the "center angle" of the curve of Spee varies proportionately with the size of the teeth, the size of the skull, or the degree of prognathy of the skull.

5. (a) Spee's conclusion that there is a close relation between the radius of the curve of Spee and the inclination of the fossa mandib-

ularis is not supported, the data on these two measurements failing to indicate a definite relationship (see tables).

(b) The existence of the curve of Spee was established in animals which have the tuberculum articulare, as well as in some animals (e.g., the muskrat) without the tuberculum. Even among animals which have the tuberculum, the teeth do not always exhibit the curve of Spee, but in some cases (e.g., the wild pig) lie in a straight line. Therefore the existence of the curve of Spee is not necessarily associated with the presence of the tuberculum articulare.

(c) Spee's opinion, that the path of the lower jaw during its antero-posterior movement is on the curve of Spee, cannot be accepted. The arguments on this question, from the standpoint of the mechanism of the jaw during mastication, as well as from the morphological examination, are presented in the text. I am therefore inclined to believe that the curve of Spee is not closely related either to the manner of movement of the lower jaw, or to the efficiency of mastication.

6. A reciprocal relation between the value of the "center angle" of the curve of Spee and the value of the angle of the line of articulation to the basio-nasal line (articular basio-nasal angle), was found in the primates, with the exception of man.

7. The real significance, physiological and anatomical, of the curve of Spee is not clear.

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THE ENDOWMENT FUND FOR THE SUPPORT OF THE JOURNAL OF DENTAL RESEARCH

SECOND REPORT

WILLIAM J. GIES

On page 5 of this volume it was stated that "the JOURNAL of DENTAL RESEARCH will be financed, *as a University is supported*, with *public-spirited special gifts for this purpose* and from a *cumulative, permanent, endowment fund to be created;* also from subscriptions for its successive volumes—*not from advertisements of goods for sale.*"

Our first report, giving the names of thirty-three contributors of a total of $2,026.00 to this fund, was published on pages 33 and 34 of the preceding issue of this JOURNAL.

This number of the JOURNAL goes to press during the last week in June, a few days after our first report, as given in the delayed March issue, was finally revised for publication. I am glad, however, to be able to report three additional generous contributions, received from the firms named below:

Borine Manufacturing Company, 551 West 42nd Street, New York City.
Lincoln Dental Manufacturing Company, 1215 Filbert Street, Philadelphia, Pa.
Philadelphia Dental Laboratory, Philadelphia, Pa.

The last edition of *Polk's Dental Register* presents, on pages 37 to 39, the names of one hundred and forty-five firms or individuals engaged in business that dentists are urged, through advertisements in the *Register*, to patronize. On May 16, I sent to each of the one hundred and forty-five firms or individuals thus designated, presumably the leaders in dental business in this country, a circular letter signed by me, of which the following is a copy:

"The JOURNAL OF DENTAL RESEARCH appeals openly, to all who are interested in the advancement of dentistry, for unqualified and unconditional financial support of its effort to promote research in every phase of

stomatology. *The new journal will not publish advertising matter. It will not be conducted for the benefit of any commercial phase of, or organization in, dentistry.*

"We believe, however, that those who are participating in the business of producing and selling dental supplies will welcome an opportunity *unselfishly* to support a journal that will be conducted solely for the stimulation, promotion, and publication of dental research. In this conviction we invite your attention to the enclosed prospectus, endowment-fund blank, and subscription card, pertaining to the JOURNAL OF DENTAL RESEARCH. We hope to receive a reply at your early convenience."

The responses to this letter, to the date on which this report is written (June 23), so far as number of contributors to the endowment fund is concerned, are listed in the above summary of three names.

I believe that those who are engaged in dental business are much more interested in the success of dental research, and of unselfish scientific journalism designed to promote such research, than this numerically meagre response would seem to indicate. I am hopeful that, after the appearance of the earlier numbers, when the character of this JOURNAL will be plainly evident, dental business men will generously coöperate with us in maintaining a journal that will be devoted whole-heartedly to dental research, and to the advancement of the *profession* of dentistry—a journal from which no one can ever expect to receive anything but information and inspiration that will be available to everybody.

The JOURNAL OF DENTAL RESEARCH will publish, in the concluding number of each successive *volume, a standing cumulative list of the names of the donors to this fund*, as a recurrent testimonial to the generosity of those who will thus have become the founders of the first research journal to represent dentistry in particular and stomatology in general.

Contributions to this permanent endowment fund, *in any amount*, are invited from all who may be interested in the welfare and continuing success of this Journal. Checks and money orders should be made payable to the Journal of Dental Research, Inc., and forwarded to the writer at the address given below.

Biochemical Laboratory of Columbia University,
College of Physicians and Surgeons,
437 W. 59th St., New York City.

SCIENTIFIC PROCEEDINGS OF DENTAL AND STOMATOLOGICAL SOCIETIES

SECOND SECTION

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A LIST OF THE NAMES OF THE ORGANIZATIONS THAT HAVE VOTED TO MAKE THE JOURNAL OF DENTAL RESEARCH THE MEDIUM FOR THE OFFICIAL PUBLICATION OF THEIR SCIENTIFIC PROCEEDINGS

ASSOCIATION OF THE ALLIED DENTAL SOCIETIES, INC.

AMERICAN ACADEMY OF DENTAL SCIENCE

MASSACHUSETTS DENTAL SOCIETY

COLUMBIA UNIVERSITY BIOCHEMICAL ASSOCIATION

In the case of the last named organization, only the dental and stomatological parts of its proceedings will be published in this JOURNAL.

A standing general invitation is extended to dental and stomatological societies, everywhere, to add their names to the above register.

PROCEEDINGS OF THE AMERICAN ACADEMY OF DENTAL SCIENCE

HORACE L. HOWE, *Editor*

Meeting held, January 8, 1919. Young's Hotel, Boston, Mass. President Dr. William Rice in the chair.

Scientific proceedings. Paper read by Dr. Augustus S. Downing, Assistant Commissioner of Education, and Director of Professional Education, of the State of New York, Albany (pages xxxiii–xlv). *Discussion* (not reported by the editor) by Drs. Frank W. Wright, Deputy Commissioner of the Massachusetts Board of Education; H. C. Bumpus, President of Tuft's College; Eugene H. Smith, Dean of the Dental School of Harvard University; and Henry Pennypacker, Headmaster of the Boston Latin School.

STANDARDS FOR DENTAL EDUCATION AND PRACTICE

AUGUSTUS S. DOWNING

Albany, New York

I am highly honored and greatly pleased to be offered the opportunity of speaking before the American Academy of Dental Science upon the subject of "Standards for dental education and practice."

For a number of years the subject of standards for medical education has been before the American Medical Association and the Council of American Medical Colleges for discussion, with a view to waging to a final settlement the struggle for that which the best men of the medical profession stand for as right standards for medical education, both in entrance requirements and in professional training in the schools themselves.

It has been my good fortune during these years to represent New York at the meetings of these associations and to maintain the position which our State has taken on this subject. New York is in a class *sui generis*, as you know, because of her centralized educational system. The University of the State of New York is charged with the responsibility of administering all of the professional laws. In its several professional statutes,

the Legislature has provided for entrance requirements; for professional requirements, and for the registration of professional schools of every character, within and without the State. The law definitely charges that the University in its administration of the laws shall not discriminate against the schools and the students who are in those schools in the State of New York in favor of schools and of students in the schools outside the State. Consequently he who administers the professional laws of New York, whether it be the present incumbent or the man who preceded or shall follow him, must always be in the position (without desiring it) of running counter to the provisions of the law in other States and to the requirements for admission to schools outside the State, if such requirements do not meet the standards fixed by the University of the State of New York. At present, it falls to my lot to advocate and to defend the position of the Board of Regents and of the University in these matters.

The administration of the educational laws in New York is entirely without prejudice for the reason that the Deans (who constitute the Dental Council), the Board of Examiners who deal with the question of licensing applicants, and the Board of Regents (the legislative body with reference to these matters) work in perfect unison, and make advances only when the schools of our own State and the best schools throughout the country can meet such advanced requirements. There must always be a number of schools that cannot at the moment meet such advances, whether it be in medicine, or in law, or in dentistry; but such schools, if they are sincere in their purpose, and worthy to exist, will ultimately exact the higher requirements.

The medical schools at first declined to meet an entrance requirement of one year of a college course in liberal arts and sciences. Ultimately they met that requirement. Then they refused to come to two years of college work for entrance. After a time they came. At first they did not want to require English, a modern foreign language and the three sciences; but they came to do this after a time; and now all the good medical schools of the country are recognized and registered by the Board of Regents of the University of the State of New York.

As I stated in Chicago, in August last, the dental profession is American born. It is not inclined to be a pacifist in its attitude toward the conservation of public health. The first recognized dentist in the world (if I am correctly informed) was a man by the name of Greenwood. He dates back to 1790. The Baltimore College of Dental Surgery, organized in 1837, was the first dental school in the world. The first dental journal in the world was published in 1840, and in that same year the National Asso-

ciation of Dental Surgeons was organized, which was the pioneer of all dental associations in that it has done so much for the advancement of dental surgery.

It is not to be wondered at, then, that the dental profession has taken such an active part in the great war for freedom from autocracy, and that upwards of 5000 men of your profession were enlisted, and a large proportion of these 5000 were in actual service in the cantonments and across the sea, with our own armies and with the French, the British, and the Italian armies—in fact, everywhere, where there were allied forces, your profession was doing its duty and performing its patriotic service. No wonder that you are proud of that.

In speaking of standards, I am reminded of what Bob Burdett once said: that "you should always use yourself as an illustration for you better than anybody else know your own cussedness." Therefore I take New York as an illustration all the time and present to you her requirements and her reasons for setting up such standards, for I know New York's "cussedness," as many regard it, and consider myself an integral part thereof.

For a full understanding of this paper, I must respectfully ask you to accept or reject a few fundamental premises upon which our conclusions rest. I hope that you will feel at liberty to discuss these premises and whatever else may be said, most freely and frankly, for New York is not thin-skinned nor is her present representative; nor have we any desire other than to protect the interests of the public, by promoting the best interests of the profession.

Then, (1) dentistry is a profession by legal enactment under the provisions of the public health law. A profession does not become such in any State until there is a statute enacted by the Legislature and signed by the Governor creating such profession. Every State in the Union has its public health laws. In these laws, dentistry is included as a profession. That being true, dentistry must meet the definition of a profession.

(2) *Definition of "profession."* The word "profession" assumes proficient attainments in special knowledge as distinguished from mere skill, and the practical application of such special knowledge *in use for others* as a vocation, as distinct from its pursuit for one's own use or benefit. For dentistry it implies specialized knowledge and peculiar skill in the application of that knowledge for the benefit of another.

(3) Schools are necessary for imparting this special knowledge and for demonstrating its practical application to the conservation of public health, and to the imparting of the true professional spirit to the men who are to carry on the profession.

(4) Adequate academic education is an essential prerequisite for entrance to such schools.

(5) Systematic arrangement of this special knowledge in a course of study that will give to those who complete the curriculum the fullest possession of such knowledge and the highest skill in applying it for the benefit of others is vital.

(6) To the end that men who do satisfactorily secure this special knowledge and high skill may have an opportunity to serve the public, and that no others shall have that opportunity, there must be established, by the State, standards of examination for a license to practice the profession.

All the altruism of professional life is summed up in the definition I have given of a "profession," whether in medicine, law, dentistry, or any other profession. If you claim the title of "profession" for your vocation, you have forever surrendered for that vocation as a primary purpose, your own benefit, your own aggrandizement, your own self; and you are morally bound, whatever the profession may be, to take into account first the benefit of those others whom that profession is to serve. The altruism of the profession which involves questions of public health is of a type wholly different from that which may actuate the other professions, such as law, accountancy, et al.

The failure to lay hold upon the content of this definition is the source of all the trouble which dentistry both in its practice and its educational institutions, is heir to. Not a small minority of dentists look upon their vocation as a commercial enterprise or venture. They unblushingly advertise their professional knowledge and professional skill as a hardware merchant advertises his wares. They compete for patronage as a carpenter or plumber solicits trade. They have no professional sense. They have none of the thrill of professional spirit that actuates a man who has only the interest of humanity at heart. Many of the dental schools, in their management, are actuated by the same commercial notions that actuated the advertising of unprofessional but licensed dentists. In fact, many of the instructors in good dental schools lose sight of, or, at least fail to imbue their students with, the spirit of the profession; those schools of dentistry that are independent of college or university affiliation, that are dependent upon tuition fees for their maintenance, that divide the surplus of earnings among the instructors, are naturally and necessarily purveyors of the commercial spirit among their students. They are naturally opposed to right entrance requirements and to right professional instruction. They make the most of the mechanics of dentistry and fail to lay stress upon the scientific knowledge required for its right practice. In these respects your pro-

fession is far behind the medical profession. Medicine has driven to the wall (because they have made them of no account in the estimate of the public) proprietary medical schools. The dental profession is still cursed with the existence of a large number of such proprietary dental schools. There are still too many dental schools that are wholly dependent for their maintenance upon the students' fees. The commonwealths in which such schools are located and which are responsible for their existence, have not come to a full realization of the true purpose of any professional school. The only justification for the existence of any professional institution is its willingness to train men who will devote their lives to the conservation of public interests. The time has arrived when no professional school should be permitted to be incorporated, or to start upon its career without incorporation, unless it is an integral part of a college or university. In my own State two of the four dental schools are as yet not parts of a university, but I prophesy that within five years there will be no such independent dental school in New York State but that all will be under university jurisdiction. The two independent schools of my State have, however, ceased to be in any sense proprietary, through the advancing requirements set by the Board of Regents.

The third premise, namely, that schools are necessary for imparting this special knowledge and for demonstrating its practical application to the conservation of public health, and to the imparting of the true professional spirit, to the men who are to carry on the profession, is at the present time indisputable so far as procedure as to standards is followed in the majority of the States in the Union. Formerly it was not so. As far back as 1868, which marks the enactment of the original dental statute of the State of New York, it was provided in section 8 that "all students who shall have studied and practised dental surgery with some accredited dentist or dentists for a term of four years should be entitled to an examination by the Board of Censors." The privilege of taking the examination after study in a preceptor's office was continued in every dental statute enacted in our State up to 1896. In that year the statute provided that all students that had filed with the secretary of the State Board of Censors a statement of the beginning of the study with a preceptor might, after four years of study, take the dental examination before the Board of Dental Examiners (the State Board of Censors having ceased to exist through the provisions of the law of 1895, by being made the State Board of Dental Examiners under such law). And in 1896 the examinations given by the State Board of Dental Examiners were virtually the same kind of examinations as had been given formerly by the State Board of Censors. Under the amended law

of 1902, extension of time was made, so that the student under private preceptorship who was entitled to file on or before July 31, 1895, a certificate, might at any time before January 1, 1904, file the certificate and be admitted to the examination. All subsequent amendments to the dental practice act have omitted provision for admission of apprentice dentists to the licensing examination; and all amendments subsequent to that of 1902 have provided for exclusive examination of students who should be graduated from dental schools registered by the State Board of Regents. I ought to say that there are still some States in the Union that do not require professional training in a school. These States are still laboring under the delusion that dentistry is a vocation and not a profession; that dentistry is largely a mechanical vocation, the successful practice of which is based upon manual dexterity and skill rather than upon scientific professional knowledge. Naturally, these States or representatives from these States would not acknowledge this imputation, but their procedure in the licensing of men to practise dentistry is confirmatory of at least the right to make the assumption.

The fourth premise, namely, that adequate academic education is an essential prerequisite for entrance to such schools, is an admitted fact, with wide difference of opinion of the meaning of the word "adequate." In the beginning, a man who had not completed even a grammar school course was eligible to register as an apprentice in a dentist's office, just as a boy in his early teens could be bound or might bind himself to a carpenter to learn a purely mechanical trade. But as time went on, it became evident to those who were most seriously concerned, namely, the preceptors, that it was impossible to teach their apprentices to become skilled dentists unless they had had at least a grammar school education. And when schools began to be established, even though they were purely commercial in purpose, the reputation of the school and consequently its commercial success depended upon the product of the institution; and the instructors in the school soon found that young men who had had only a modicum of education were incapable of taking the training, and one school after another established entrance requirements, some higher and some lower. Our own State, when the administration of the professional laws was charged as one of the duties of the Board of Regents, established, for all of the professions, entrance requirements to professional schools to be recognized by them; and the statutes governing the respective professions fixed the minimum, prerequisite, academic education for admission to the school: at first one year of high school, then two, then three and at last four. The statute of 1916 made the presentation of a dental student certificate to the dental

school a necessary act before such school might matriculate the applicant for admission; and further left it in the hands of the Board of Regents to prescribe the course of study for admission to the school.

In our State there are three factors in advancing the educational requirements:

(a) The State Board of Dental Examiners, who are all members of the dental profession and are supposedly familiar with the requirements of the profession.

(b) The State Dental Council, which is composed of the deans of the dental schools. These men are certainly familiar with all of the problems involved in right dental education, and the condition of the profession: for example, as to the supply of students and the demand for practitioners. This factor, better than either of the other two perhaps, is in position to say whether an advance in the prerequisite entrance requirements will seriously affect the attendance upon a school by curtailing the number of students, and whether such curtailment of the student body will react disastrously upon the supply of practitioners and therefore be harmful to the interests of public health.

(c) The Board of Regents is the legislative body, for this Board approves, by enactment into rule, the conclusion which may be reached by joint agreement of themselves and the other two factors.

Therefore, after a considerable number of years (during which the requirements for admission to *medicine* had advanced first to the satisfactory completion of a four-year high school course; then to the including in such course a year of physics, chemistry and biology; then the requirement of a college year, including college work in these three sciences, and a modern foreign language and English; and then two years of college work with the same requirements as to science, English and modern foreign language); the requirements for admission to the study of *dentistry* during the same period having only reached a requirement of four years of high school work, in 1913 such prerequisite four-year high school course was made to include at least two of the three sciences; and after January 1, 1916, a year's work in each of the three sciences.* All of the schools in the State of New York

*Subsequent to the reading of this paper the Board of Regents of the University of the State of New York have made the following rule:

"A dental student certificate may be secured, after January 1, 1921, upon the presentation of satisfactory evidence of the completion of not less than one year of instruction in an approved college of liberal arts and science after the completion of an approved four-year high school course based upon eight years of elementary preparation. The year of college instruction must be of at least 15-week hours, including English (3), physics (3), biology (3), and chemistry (3)."

were able to exact such requirement even though it did curtail the number of students that were admitted; and, moreover, because of the centralized system of educational administration in our State, there could be no juggling with the entrance requirement which any student might present for admission, for every student admitted was required and is required to present to the registrar his dental student qualifying certificate issued by our Department, or a letter stating that he is entitled to such certificate and that the same will be issued at the earliest date possible, when the applicant for admission presents himself for matriculation.

The debatable question then, at this point, may be stated as follows: Is an elementary knowledge of the principles of physics, of chemistry and of biology prerequisite for the right study of dentistry? The three factors mentioned above as determining prerequisites are in perfect agreement that such preliminary elementary knowledge is fundamental. This conclusion is based upon an affirmative answer to either or both of two questions, namely, may dentistry legitimately be considered a branch of medicine? Or, is dentistry so closely allied to medicine that many of the diseases treated by the medical practitioner may have their origin in diseased conditions of the teeth? Not a single sane instructor in any medical school in the country questions the fact that at least an elementary knowledge of physics, chemistry and biology is a fundamental prerequisite to the study of medicine. If, then, the questions asked above are answered affirmatively, there can be no negative to the proposition that an elementary knowledge of physics, chemistry and biology must be fundamental and a prerequisite to the study of dentistry. But the answer comes invariably that our high schools do not teach biology. My answer is that it's high time that they did. All the approved high school courses in the State of New York include physics, chemistry and biology. It is true that a student is not required to take all three, but if he is going into dentistry he ought to take all three. In place of the biology course there are also included in the high school courses the electives: a half year of botany, a half year of zoology, or a half year of physiology, or year courses in each of these subjects; and we have always accepted the half year of zoology and the half year of botany as meeting the biology requirement, if the student had physiology in his grammar school course, or if he had the half year of physiology in the high school course.

The argument is made by those who are unable to meet this prerequisite of the three sciences, that you are forcing the boy to make his choice of his life's work in the early years of his high school course, and that many boys do not know until after they have gone through three years, or even four

years, that they want to study dentistry, and that these individual boys ought to have their chance to enter the school on two sciences or even one science and to make up their deficiencies after they have entered the dental school. There is nothing to this argument if you accept the definition of "profession," which I have given, namely, that the profession is for the conservation of the public health of a community and is not primarily for the individual. This individual or the few individuals who find themselves debarred from entrance to a professional school, because they happen to be deficient in physics or in chemistry or in biology, or in two of these subjects, can't make up the deficiency during the time they are taking the professional course. You can't lay the foundation to a house while you are building the first story or the second story or the third story or the fourth story. The boy who finds that he wants to enter dentistry, but has not the prerequisite academic knowledge to properly study the subject, should wait another year and acquire that knowledge, to the end that he may better fit himself for his life's work and to the end that the dental school may be assured that the man will not be a menace to the public when he is graduated.

The university schools of dentistry argue that this boy should be given the privilege of making up his science deficiency in the college of liberal arts and science while he is taking his dental course. It is the old cry of the university medical schools years ago. New York was slow to require the three sciences in medicine as a prerequisite, until it believed that the schools would not be seriously disturbed in their student body, and until such a time when it was generally believed that the exactment of such prerequisite was for the good of the public. The same is true of the exactment of two of the sciences after January 1, 1913, and then the exactment of three sciences after January 1, 1916, for admission to the study of dentistry. But in this entrance requirement the public suffers, the profession suffers and, I believe, the schools suffer, because the schools are not honest with themselves and honest with each other in the enforcement of entrance requirements which they say they will enforce. The schools of New York have no option in enforcing them and no chance not to enforce the requirements, because they cannot admit students without a dental student certificate issued by our Department and signed by me, unless I am to be away from the office for a considerable number of days.

It may seem to you that my statement that the schools are not honest with themselves and with each other is too severe an arraignment of those who have charge of the admission of students, but I have conclusive evidence of this in the files of the Department. When we announced this advancing requirement, two schools protested upon the ground that they

could not meet the advance. In order to show that the applicants could not present three sciences, these two schools analyzed the entrance credentials of the class of 1915; and in such analysis both of them conclusively demonstrated that more than 50 per cent of the entrance class did not have even two sciences, although the deans of these schools, in applying for registration by the Board of Regents, had made affidavit that they would exact entrance requirements not lower than graduation from a four-year high school course of study, including a year of two of the three sciences: physics, chemistry, biology. These are not the small, inconsequential, commercial schools. One is a university school and the other an independent school, and both of them recently classified as "A" schools.

I have presented this matter to you at length for the reason that many of the dental schools of the Commonwealth will not appear on the list of schools registered by the Board of Regents next year. Will the schools here represented be among those that must be omitted from the list?

"(5) Systematic arrangement of this special knowledge in a course of study that will give to those who complete the curriculum the fullest possession of such knowledge and the highest skill in applying it for the benefit of others," is vital. Like its kindred, medicine, dentistry has passed through successive stages of advancement of the professional requirement, from two years of study to three years, and now to four years. But the duration of the course of study is only one element in the determination of its value. Content must go *pari passu* with length of time. For many years it was deemed that a three-year course of study was sufficient for the proper preparation of a man for entrance upon the practice of dentistry. Effort in recent years was repeatedly made to increase the length of the course from three to four years. New York consistently opposed such increase on the ground that the schools would get another year's tuition without giving adequate return in professional knowledge and skill. It was proposed to add to the course more academic training to make up for the deficiencies which the high school students might show in English, in sketching, in chemistry, physics, biology, penmanship, et al. From the standpoint of a profession that proposal was in no way honest. From the standpoint of a private high school or a private preparatory school, it could not be criticised, but from the standpoint of an institution whose sole existence is justified because it prepares men for public service in matters pertaining to health, it was indefensible. When, however, it became the judgment of the three factors interested in advancing requirements that the public weal demanded a broader professional training for dentists than it was possible to give in a three years' course, New York advanced its professional course

of study in length from three to four years, and the Board of Dental Examiners, and the Deans of the Schools and their Faculties, were charged with the responsibility of presenting a purely professional course to the Board of Regents for approval, cutting out all so-called ancillary subjects which, in my judgment, have no place in a professional course. In the course approved by the Board of Regents (copy of which may be found in the dental handbook, several of which I have with me) you will note a mild exception to this statement in that we provided, for general chemistry, 180 hours in the first year's course—60 recitation and 120 laboratory hours. This seemed only fair for the reason that a number of outstanding dental student certificates had been issued when chemistry was not a required subject, but which are valid for presentation to a dental school at any time after their issuance. It is contemplated that this requirement in chemistry will be eliminated in two years from now—probably, one year—and that additional professional work will be substituted for such academic instruction.

It was further believed that 4000 hours should be the minimum course of study: 1000 hours each year. If any school wanted to add to this number of hours, it might do so; but in dentistry as in medicine, I, for one, am confident that the men are hurried from one recitation to another; that the work is so heavy that there is little time for reflective consideration of the instruction given; and that it would be better to have fewer hours than obtain in most schools, and demand a severer exactment of accurate comprehension of the instruction given, which can only be secured by reflective consideration on the part of the student of the instruction given. The ancillary subjects are high school subjects of study; and New York believes that it is an economic waste to include such subjects in a professional course. It is a far better public policy to bring schools to the pupils than to bring pupils to the schools, and a man who is entering a professional school should be able to get his full preparation for such professional study at his home, where his living expenses can be had at cost; and he should not be taken away to a professional school where he is charged a high rate of tuition for instruction that he was entitled to have at home, and at the same time be robbed of the opportunity of acquiring the professional knowledge and skill which will enable him to serve the public best, and afford him the opportunity of becoming a high grade practitioner.

Moreover, medicine and dentistry are so closely allied that dentistry is now once more coming into its own. The two professions are coming together, and no medical school, worthy of the name, pretends to give a course of study that is not strictly professional, within the full meaning of that term. In the dental course are included the subjects of anatomy,

pathology, histology, physiology, bacteriology, the same as in medicine. These subjects should be taught in the dental schools as thoroughly and as well as they are taught in the medical schools. In the courses of study approved by the teaching faculties of the university schools and of the independent dental schools, the fundamental principle that you cannot combine professional training and the acquiring of academic knowledge fundamental to such training, has been ignored. In Chicago I spoke (for example) of the including of dental rhetoric, free hand drawing, and similar academic subjects, and the assigning of a number of hours under the blanket term "and other subjects." Such courses cannot be approved as meeting the requirements of New York State. If the courses in the university schools and the other good dental schools of the country meet the minimum number of hours in the approved four-year course, as published in our announcement and as exacted in our schools, and they then choose to add a lot of other subjects, and if the instruction given in the professional courses is equal in grade or rank with those given in New York, there can be no objection to registering these schools, but otherwise these schools cannot be included in the registered list.

The dental curriculum is one of the most vital subjects that can be brought before a body such as this, for, upon the integrity of this course must depend the future of the profession, and the respect which dental schools and dentistry itself will command among professional men and among educated men and women generally.

"(6) To the end that men who do satisfactorily secure this special knowledge and high skill may have an opportunity to serve the public and that no others shall have that opportunity, there must be established by the State, standards of examination for license to practice the profession." In our own State the first standard for examination is evidence that the applicant for examination is over twenty-one years of age and has met all the preliminary and professional educational requirements, and that he has been graduated with the degree of D.D.S. from a dental school registered by the Board of Regents; and, second, that he has attained a rating of 75 per cent or more in each of the following subjects: Physiology and hygiene, chemistry and metallurgy, oral surgery and pathology, operative dentistry, prosthetic dentistry, therapeutics and materia medica, histology, and practical examinations in operative and prosthetic dentistry. When an applicant has met these requirements, we believe that he should be allowed to practice his profession, and that a candidate who cannot meet these requirements, should not be so allowed.

There is one more requirement for the protection of the profession, secondarily, and for the public, primarily, that to me seems absolutely indispensable, viz, annual registration of all licensed dentists within the Commonwealth. Otherwise, in any State there will be fraud, deceit, and swindling by men who practice dentistry without requisite training and requisite skill, and without scientific knowledge; and there will be no way of protecting the public against such charlatanism. The penalties imposed for violation of the statute must be severe and the enforcement of the statute must be thorough. I commend to your State the present dental law in force in the State of New York. It is the opinion of the best men of your profession, men who have given their lives to the study and upbuilding of the profession, that it is far and away the best dental law in the United States.

The scientific advance of the past few years finds the profession of dentistry hardly equipped to solve the daily problems and to meet the responsibilities of a thoroughly professional dental practice; and yet no field offers greater opportunity for distinguished service. The highest honors are waiting for the men who have prepared themselves by thorough education and careful painstaking study for their task. The reward of a grateful public, both in name and in possession of worldly treasure, are waiting for bestowal upon such men. Virtually a hundred per cent of all the medical schools worthy of the name require at least two years' college preparation for admission to the study of medicine. Shall dentistry admit that it will continue to be not as learned a profession as that of medicine? Shall it go on satisfied with being characterized as a vocation and not strictly a profession? Shall it fail to rise to its opportunities and to its responsibilities? Study if you will, as I have, the training of the men who are the deans of our dental schools, and of the men who are instructors therein, and you will be appalled by the small number of these men who have had a broad academic training, who have become distinguished because of their professional knowledge and their professional skill. It is to my confident belief in the greatness of the profession of dentistry, in its opportunity to serve mankind, that can be attributed the persistent, untiring effort for and defense of the higher standards for dental education and dental practice, which I am bound to make so long as it shall be my opportunity as well as my duty to administer the professional laws of the Empire State.

Once more, may I say that I appreciate the courtesy of the invitation to come to talk to you, and I cordially invite your discussion, your criticism —whether favorable or adverse—of the six premises laid down in this paper and upon which are based all of the deductions found therein.